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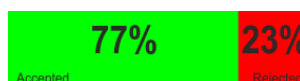


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COGNITIVE MODEL: THE DUNNING-KRUGER EFFECT

Abstract: The process of "influence on the degree of a student's subjective self-assessment of their abilities, skills, and competencies" was formalized. The introduced parameters and variables numerically measure how much the manifestation of one factor is greater or lesser than the manifestation of another factor. This made it possible to calculate all the model strengths of the manifestations of a student's subjective self-assessment of their abilities, skills, and competencies and evaluate the daily values of the degree of assessment over 25 days.

The model deviations of the parameters $z_{il} \cdot c_{kl}$ (the k -th manifestation factor (out of 4) were found in the i -th practical session. The matrices U_{m4} ($\text{rang}(U_{m4})=4$) and Y_{m4} ($\text{rang}(Y_{m4})=1$) were modelled separately such that $(1/m)U_{m4}^T U_{m4} = I_{44}$, $Y_{m4} = U_{m4} A^{1/2}_{44}$, $Z_{m4} = Y_{m4} C^T_{44}$ ($\text{rang}(Z_{m4})=4$). The matrix of values of z -variables z_1, z_2, z_3, z_4 $Z_{m4} = Y_{m4} C^T_{44}$ has a covariance matrix, not a correlation matrix, since its pseudo-eigenvectors satisfy the relations $C_{m44} C_{44} \neq I_{44}$, $C_{44} C^T_{44} = I_{44}$. A system of multi-meaning equations with 4 semantic unknown variables was developed, one of its solutions was found in the form of a phrase from a compound sentence. A formula for the magnitude of the degree of subjective self-assessment of a student's abilities, skills, and abilities has been derived: $y_1 = 0.8385 \cdot z_1 + 0.1778 \cdot z_2 + (-0.9491) \cdot z_3 + (-0.9491) \cdot z_4$. The new meaning (y_1) is constructed as the sum of newly obtained z -meanings from the meaning equation $\text{meaning}(y_1) = 0.8385 \cdot \text{meaning}(z_1) + 0.1778 \cdot \text{meaning}(z_2) + (-0.9491) \cdot \text{meaning}(z_3) + (-0.9491) \cdot \text{meaning}(z_4)$. The following extracted knowledge inspires optimism: the phrase with new meaning (y_1) contains the words – with a strength of $(0.9491)^2$, which reduces "his inability to recognize the full depth of his incompetence is more severe" and "after training, his ability to recognize the level of his previous incompetence greatly increases." With this knowledge, the model predicts a return to an accurate assessment of one's abilities, skills, and abilities in the future. The model demonstrated predictive ability.

Key words: The Dunning-Kruger effect, the degree of subjective self-assessment by a student of his abilities, skills, and abilities, stimulating factors in a student, a cognitive model of the process, Inverse Principal Component Model.

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КОГНИТИВНАЯ МОДЕЛЬ: ЭФФЕКТ ДАННИНГА-КРЮГЕРА

Аннотация: Проведена формализация процесса «влияние на степень субъективной самооценки студентом своих способностей, навыков, умений». Введенные параметры, переменные численно измеряют, показывают во сколько раз проявление одного фактора больше/меньше проявления другого фактора. Это позволило вычислить все модельные силы проявлений субъективной самооценки студентом своих способностей, навыков, умений» и оценить однодневные величины степени оценки за 25 дней. Найдены модельные отклонения параметров $z_{il} \cdot c_{kl}$ (k -го фактора проявления (из 4), в i -ом практикуме. Отдельно моделировались матрицы U_{m4} ($\text{rang}(U_{m4})=4$) и Y_{m4} ($\text{rang}(Y_{m4})=1$) такие, что $(1/m)U_{m4}^T U_{m4} = I_{44}$, $Y_{m4} = U_{m4} A^{1/2}_{44}$, $Z_{m4} = Y_{m4} C^T_{44}$ ($\text{rang}(Z_{m4})=4$). Матрица значений z -переменных z_1, z_2, z_3, z_4 $Z_{m4} = Y_{m4} C^T_{44}$, имеет ковариационную, а

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не корреляционную матрицу, ибо ее псевдосо собственные векторы удовлетворяют соотношениям $C_{m44}C_{44}=I_{44}$, $C_{44}C_{m44}=I_{44}$. Разработана система многосмысловых уравнений с 4 семантическими неизвестными переменными, найдено одно ее решение в виде фразы из сложносочиненного предложения. Выведена формула величины степени субъективной самооценки студентом своих способностей, навыков, умений: $y_1=0,8385*z_1+0,1778*z_2+(-0,9491)*z_3+(-0,9491)*z_4$. Новый смысл(y_1) конструируется как сумма вновь полученных z-смыслов из смыслового уравнения $\text{смысл}(y_1)=0,8385*\text{смысл}(z_1)+0,1778*\text{смысл}(z_2)+(-0,9491)*\text{смысл}(z_3)+(-0,9491)*\text{смысл}(z_4)$. Оптимизм внушает следующее извлеченное знание: фраза нового смысла(y_1) содержит слова – с силой $(0,9491)^2$ уменьшает «его неспособность осознавать всю глубину своей некомпетентности более сильна» и «после обучения очень сильно появляется у него способность осознать уровень своей прежней некомпетентности». Этим знанием модель предполагает в будущем возвращение к правильной оценке своих способностей, навыков, умений. Модель проявила прогнозную способность.

Ключевые слова: Эффект Даннинга-Крюгера, степень субъективной самооценки студентом своих способностей, навыков, умений, стимулирующие факторы у обучающегося, когнитивная модель процесса, Обратная Модель Главных Компонент.

Введение

Эффект Даннинга-Крюгера (ЭДК), часто упоминаемый в политическом контексте, стремительно превратился в широко известную психологическую концепцию. Он описывает своего рода двойную проблему [1-15]. Если вы подвержены действию эффекта Даннинга-Крюгера, то не только мало знаете о предмете — что само по себе плохо, — но и пребываете в ложном убеждении, будто ваши знания гораздо обширнее, чем на самом деле [11,15]. В мире, где мнения экспертов регулярно игнорируются, а многие интернет-пользователи полагают, что разбираются в медицине и внешней политике лучше тех, кто профессионально изучал эти дисциплины, эффект Даннинга-Крюгера, по-видимому, многое объясняет. Люди, не обладающие навыками или знаниями в какой-либо области, также страдают от «метакогнитивного дефицита». Метакогниция — это размышление о собственных мыслительных процессах; она отличается от обычного мышления, задействованного при решении задач или прохождении тестов. По мнению Даннинга и Крюгера [11,15], люди, не владеющие достаточной информацией, зачастую даже не осознают этого. Статья «The Dunning-Kruger effect revisited» (2017) подтверждает, что некомпетентные люди переоценивают свои способности из-за отсутствия метапознания, а высококвалифицированные люди склонны недооценивать свои успехи. Исследование защищает теорию эффекта Даннинга-Крюгера от критических замечаний.

Суть эффекта изложим в рамках второго эксперимента, описанного в оригинальной статье Крюгера и Даннинга (Kruger and Dunning 1999). Студентам колледжа предложили пройти тест на логическое мышление из двадцати вопросов, взятых из вступительного экзамена для юридических вузов (LSAT). После выполнения заданий каждого студента просили оценить свои результаты (с применением только своих способностей, навыков, умений) по сравнению с остальными

участниками (используя процентильную шкалу), а также спрогнозировать количество правильных ответов. Представляя результаты, Крюгер и Даннинг разделили участников на группы (например, 25% участников с самыми низкими результатами, следующие 25% и так далее). Классический результат этого исследования показали на рисунке - гипотетическом графике, который я построили на компьютере. Люди, показавшие низкие результаты по сравнению с остальными, существенно переоценивали качество своего выполнения теста. И наоборот: участники, попавшие в верхнюю группу, несколько недооценивали свои достижения. Подобные результаты неоднократно воспроизводились разными исследователями в различных лабораториях в ходе экспериментов с участием самых разных испытуемых [1-7]. Наиболее распространенный подход к измерению эффекта Даннинга-Крюгера заключается в сопоставлении самооценки с объективными результатами выполнения задания. Самооценку студента иногда называют «субъективной способностью» в противовес «объективной способности», соответствующей реальным результатам.[8] Самооценка может проводиться как до, так и после выполнения задания.[10] Если она проводится после, участники не получают в процессе выполнения никаких независимых подсказок о том, насколько хорошо они справились. Так, если задание предполагает ответы на вопросы викторины, участникам не сообщается, был ли конкретный ответ правильным.

Исходные данные

Словесная модель позволяет формализовать в познающую модель явление «субъективная самооценка студента своих способностей, навыков, умений» (эффект Даннинга-Крюгера). Исходными данными являются смыслы факторов самооценки:

1 Иллюзия превосходства (пик глупости): («субъективной способностью»? (смысл(y_1)));

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2 Не способность адекватно оценивать действительно высокий уровень умений, навыков у других(смысл(y_2));

3 Не способность осознавать всю глубину своей некомпетентности(смысл(y_3));

4 После обучения у них появляется способность осознать уровень своей прежней некомпетентности, даже если их истинная компетентность после обучения практически не меняется.

Результаты в сравнении с группой сверстников (смысл(y_4)).

Формализация явления «субъективная самооценка студентом своих способностей, навыков, умений» (эффект Даннинга-Крюгера)

Измерение субъективных и объективных способностей может осуществляться в абсолютных или относительных показателях. При использовании абсолютных показателей самооценка и результаты оцениваются по объективным критериям — например, по количеству правильных ответов в викторине. При использовании относительных показателей результаты сравниваются с показателями группы сверстников. В этом случае участников просят оценить свои результаты по сравнению с другими участниками — например, определить, какой процент сверстников (сколько студентов из 100) они превзошли по баллам за экзамен.[17][13][3] Эффект Даннинга-Крюгера наблюдается в обоих случаях, однако он, как правило, значительно более выражен при оценке в относительных показателях: **люди (студенты не исключение) обычно менее точны, оценивая свои успехи на фоне группы сверстников**, чем при простом прогнозировании своего фактического балла.[18]. Познающая модель дает результат, равноправный с объективными результатами экспериментов по проверке эффекта Даннинга-Крюгера. Основным интерес для исследователей обычно представляет корреляция между субъективной (z -переменными z_1, z_2, z_3, z_4) и объективной способностью (измеряемой одной j , линейной комбинацией $y_1 = z_1 * c_1 + z_2 * c_2 + z_3 * c_3 + z_4 * c_4$, где вектор $c_1 = (c_1, c_2, c_3, c_4)$ имеет реальные объективно моделированные «веса» (c_1, c_2, c_3, c_4), создающие объективность вычисленной переменной $y_1 = z_1 * c_{11} + z_2 * c_{21} + z_3 * c_{31} + z_4 * c_{41}$; $c_{11} = \text{corr}(z_1, y_1)$, $c_{21} = \text{corr}(z_2, y_1)$, $c_{31} = \text{corr}(z_3, y_1)$, $c_{41} = \text{corr}(z_4, y_1)$).[8]

Для упрощения анализа полученных данных реальные объективно моделированные «веса» (c_1, c_2, c_3, c_4) (объективные результаты) делят на четыре группы (по шкале Чеддока): 0,1-0,3: Слабая; (0,3–0,5]: Умеренная; (0,5–0,7]: Заметная (или средняя); (0,7–0,9]: Высокая; (0,9–0,99] (1,0): Весьма высокая (сильная). Эта эмпирическая шкала, используемая в статистике для качественной оценки силы (тесноты) связи между

двумя количественными показателями, характеризуемыми коэффициентом корреляции ($\text{corr}(*, *)$). От нижнего интервала (участники с самыми низкими результатами) до верхнего интервала (участники с самыми высокими результатами).[3][8] Наиболее выраженный эффект некомпетентности (максимальные «веса» c_1, c_2, c_3, c_4 в линейной комбинации $y_1 = z_1 * c_1 + z_2 * c_2 + z_3 * c_3 + z_4 * c_4$, где $c_1 = (c_1, c_2, c_3, c_4)^T$ — 1-ый собственный вектор, соответствующий максимальному собственному числу λ_1) наблюдается у участников из верхнего интервала: при оценке в относительных показателях субъект склонен считать, что он входит в число участников двух верхних интервалов: высокий и очень высокий. Поэтому в ОЗ мы должны назначить целевую функцию вида $c_{11}^2 + c_{21}^2 + c_{31}^2 + c_{41}^2$, которая максимизируется при ограничениях $C_{44} C_{44}^T = I_{44}$, $C_{44}^T C_{44} \pm I_{44}$ (числовые формулы $c_{1j}^2 + c_{2j}^2 + c_{3j}^2 + c_{4j}^2 = 1$, $c_{1j}^2 + c_{2j}^2 + c_{3j}^2 + c_{4j}^2 \neq 1$, $j=1, \dots, 4$) $\Lambda_{44} = \text{diag}(4, 0, 0)$, $\lambda_1 = 4$, ограничениями $c_{41} > 0$, и с управляющими параметрами $c_{11} < 0.5000$, $c_{21} < 0.7000$, $c_{31} < 0.5000$, $c_{41} < 0.9000$, пределом которой является максимальное значение целевой функции вида $c_{11}^2 + c_{21}^2 + c_{31}^2 + c_{41}^2$. Условие $\Lambda_{44} = \text{diag}(4, 0, 0)$, $\lambda_1 = 4$ вводится для того, чтобы получить одно (не 4) смысловое уравнение $y_1 = 0,8385 * z_1 + 0,1778 * z_2 + (-0,9491) * z_3 + (-0,9491) * z_4$.

Пояснение выбора верхних границ «допустимой некомпетентности» через значения 4-х параметров следующее. Значение 0.5 для параметра $\text{corr}(z_1, y_1) = c_{11} < 0.5000$ формализует фразу «степень иллюзии личного превосходства у студента (в смысле фразы смысла(z_1)) не превосходит границы интервала «умеренная связь с переменной y_1 (по шкале Чеддока) с смыслом смысл(y_1)». Эта граница допускает умеренную степень некомпетентности (в смысле фразы смысла(z_2)) у студента, возможно стремящегося «сдвинуть гранит науки». Значение 0.7 для параметра $\text{corr}(z_2, y_1) = c_{21} < 0.7000$ формализует фразу «степень иллюзии личного превосходства (в смысле фразы смысла(z_3)) у студента не превосходит границы интервала «высокая связь с переменной y_1 (по шкале Чеддока) со смыслом смысл(y_1)». Эта граница допускает сильную степень некомпетентности (в контексте фразы смысла(z_2)) у студента.

Значение 0.5 для параметра $\text{corr}(z_3, y_1) = c_{31} < 0.5000$ формализует фразу «степень иллюзии личного превосходства (в смысле фразы смысла(z_3)) у студента не превосходит границы интервала «высокая связь с переменной y_1 (по шкале Чеддока) со смыслом смысл(y_1)». Эта граница допускает умеренную степень некомпетентности (в контексте фразы смысла(z_3)) у студента. Значение 0.9 для параметра $\text{corr}(z_4, y_1) = c_{41} < 0.9000$ формализует фразу «степень иллюзии личного превосходства (в смысле фразы

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смысла(z_4)) у студента не превосходит границы интервала «очень высокая связь с переменной y_1 (по шкале Чеддока) с смыслом y_1 ». Эта граница допускает очень высокую степень некомпетентности (в контексте фразы смысла(z_4)) у студента.

Эти границы повлияли на вычисленные значения ($C_{11}=0,6132$; $C_{21}=0,6905$; $C_{31}=0,4973$; $C_{41}=0,8757$), полученные при решении ОЗ с учетом условия максимума целевой функции вида $c_{11}^2+c_{21}^2+c_{31}^2+c_{41}^2$. $c_{11}<0,5$, $c_{21}<0,7000$ $c_{31}<0,5000$ $c_{41}<0,9000$.

Оптимизационная Задача

Оптимизационная Задача (I_{54}, Λ_{44})= $\Rightarrow$ (C_{44}, Λ_{44}). Пусть элементы неизвестной матрицы C_{44} псевдосообственных векторов из пары матриц ((C_{44}, Λ_{44}), Λ_{44})= $\text{diag}(4,0000,0, 0,0)$ удовлетворяют условиям: значения компонент №1, №4 1-го псевдосообственного вектора имеют знак минус: - $1<c_{11}<0$, $-1<c_{41}<0$; б) соблюдаются ограничения на матрицу псевдосообственных векторов вида $C_{44}C_{44}^T=I_{44}$, $C_{44}^TC_{44}=I_{44}$, где значения компонент 1-го псевдосообственного вектора являются линейной комбинацией неизвестных значения z-изменчивостей с c-параметрами: $y_{i1}=c_{11}*z_{11}+c_{21}*z_{12}+c_{31}*z_{13}+c_{41}*z_{14}$, $i=1,\dots,m$; в) выполнены условия однофакторности произведения матриц вида $C_{44}\Lambda_{44}C_{44}^T$, где C_{44} - матрица псевдосообственных векторов такая, что выполняются условия: $C_{44}C_{44}^T=I_{44}$, $C_{44}^TC_{44}\neq I_{44}$, $\Lambda_{44}=\text{diag}(\lambda_1,\dots,\lambda_4)=\text{diag}(4,0000,0, 0, 0)$ - заданная матрица собственных чисел. Ограничения а),б),в) сужают область поиска неизвестных составов наборов сил проявлений входят в формулы 4-х u-переменных и являются существенными параметрами когнитивной модели.

Матрица «весов» C_{44} является существенным объектом в матричном смысловом равенстве вида $\text{смысл}(Y_{m4})=\text{смысл}(Z_{m4}C_{44})$ - применяемой гипотезе в моделях из [3-15]. Модельная пара (C_{44}, Λ_{44}) матриц входит [3-5,16] в новую схему Обратной Модели Главных Компонент [21]: ((C_{44}, Λ_{44})= $\Rightarrow$ (Y_{m4}, Z_{m4}), где C_{44} - модельная матрица [17,18] значений «весов» (матрица псевдосообственных векторов, диагональная матрица Λ_{44} $\text{diag}(4,0,0,0)$ является матрицей собственных чисел, матрицы случайных чисел $Y_{m4}=U_{m4}\Lambda_{44}^{1/2}$, $Z_{m4}=Y_{m4}C_{44}^T$) $U_{m4}^TU_{m4}=I_{44}$ моделируются [17-21], интерпретируются как многомерные выборки [21] y-,z-изменчивостей. Элементы y_{1j} , y_{2j} ,..., y_{mj} j-го столбца матрицы $Y_{m4}=U_{m4}\Lambda_{44}^{1/2}$ (j-ая y-переменная, $j=1,\dots,4$) имеют среднее арифметическое, равное нулю: $(1/m)(y_{1j}+y_{2j}+\dots+y_{mj})=0$, и дисперсию равную λ_j : $(1/m)(y_{1j}^2+y_{2j}^2+\dots+y_{mj}^2)=\lambda_j$. Матрица псевдосообственных векторов C_{44} такая, что выполняются условия: $C_{44}C_{44}^T=I_{44}$, $C_{44}^TC_{44}\neq I_{44}$, матрица псевдосообственных чисел

$\Lambda_{44}=\text{diag}(\lambda_1,\dots,\lambda_4)=\text{diag}(4,0000,0,0,0)$ отличается наличием нулевых значений: $\text{tr}(\Lambda_{44})=\lambda_1+\dots+\lambda_4=4,0000+0+0+0$. Здесь одна матрица C_{44} из пары матриц (C_{44}, Λ_{44}) моделировалась программой GRD2, исходя из начальных матриц (I_{44}, Λ_{44}), используя ограничения и управляющий параметр $c_{12}=0,5000$. Эти моделируемые матрицы должны подчиняться равенствам: $C_{44}C_{44}^T=I_{44}$, $C_{44}^TC_{44}\neq I_{44}$, $\text{tr}(\Lambda_{44})=\lambda_1+\dots+\lambda_4=4$, $\lambda_1=4$, $c_{12}=0,5000$ - регулируемый параметр $=\text{corr}(z_1, y_2)$ - коэффициент корреляции между z-переменной z_1 и y-переменной $y_2=c_{12}*z_1+c_{22}*z_2+c_{32}*z_3+c_{42}*z_4$. А псевдопсевдосообственному числу λ_1 назначили значение 4 для того, чтобы ранг матрицы $C_{44}\Lambda_{44}C_{44}^T$ был равен 1. Оно является условием существования одной линейной комбинации критерием однофакторности соответствующей многомерной выборки $Y_{m4}=Z_{m4}C_{44}$ [21]. Введем в излагаемую ниже модель введены 4 семантических переменных (4 фраз смыслов) зависимых z-факторов, им соответствуют модельно вычисленные коррелированные 4 числовые z-переменные, равные значениям отклонений z вправо/влево от 0 (изменчивости проявлений z-элементов). К заданным 4 именам-смыслам модельных z-переменных, добавим ограничения. Матрица C_{44} служит индикатором [16-19] наличия скрытых знаний, поэтому сформируем для будущей пары матриц (C_{44}, Λ_{44}) 2 начальные диагональные единичные матрицы (I_{44}, I_{44}). Применяемая процедура GRD2 (из надстройки «Поиск решения») после последовательных приближений преобразует матрицы (I_{44}, I_{44}) в матрицы (C_{44}, Λ_{44}). Для процедуры GRD2, необходимы функции ограничений, помогающие процедуре GRD2 уменьшить работу при поиске решения (матрицы C_{44}).

Заданы ограничения на значения параметров и переменных модели: а) знаки «весов» $c_1>0$, $c_2<0$, $c_3>0$, $c_4>0$, б) значения весов c_1^2 , c_2^2 , c_3^2 , c_4^2 (силы c_1^2 , c_2^2 , c_3^2 , c_4^2) должны удовлетворять неравенству должны удовлетворять ограничению $c_1^2+c_2^2+c_3^2+c_4^2>1$ для того, чтобы 1-ый псевдосообственный вектор мог иметь значения (по абсолютной величине), близкие к 1. Решается Оптимизационная Задача: (I_{44}, Λ_{44})= $\Rightarrow$ (C_{44}, Λ_{44}), ее целевая функция имеет вид $c_{11}^2+c_{21}^2+c_{31}^2+c_{41}^2$, которая максимизируется при ограничениях $C_{44}C_{44}^T=I_{44}$. Было опасение, что процедура GRD2 откажется искать решение (C_{44}, Λ_{44}). Используем ограничения: $\lambda_1+\dots+\lambda_4=4$ при изменяемых значениях 4*4 элементов матрицы C_{44} , имеющей ограничения на свои элементы: $C_{44}^TC_{44}=I_{44}$, $C_{44}C_{44}^T=I_{44}$, $\Lambda_{44}=\text{diag}(\lambda_1,\dots,\lambda_4)$, $\text{tr}(\Lambda_{44})=\lambda_1+\dots+\lambda_4=4$, но без ограничений на монотонность: $\lambda_1=4$, $\lambda_2=\lambda_3=\lambda_4=0$. Особенность данной пары: матрицы псевдосообственных векторов C_{44} и матрицы псевдосообственных чисел - состоит в том, что они

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позволяют моделировать как коррелированные z-переменные (с положительными дисперсиями), так и некоррелированные y-переменные (с близкими к 0 значениями дисперсий). Применяемая процедура GRD2 (из надстройки "Поиск решения") после последовательных приближений преобразует матрицы (I_{44}, I_{44}) в матрицы (C_{44}, Λ_{44}) . Для процедуры GRD2, необходимы функции ограничений, помогающие процедуре GRD2 уменьшить работу при поиске решения (матриц C_{44}, Λ_{44}). Обращаем внимание на важность знаков «весов». Знаки плюс имеют все «веса», только «вес» c_2 отрицателен, так как уровень повиновения у учителя сохраняется долго. Знак при c_1 положителен: он подчиняется авторитету до конца эксперимента, его ожидаемое значение равно. Оптимизационная Задача даст решение, используя имеющиеся ограничения. Знак плюс при «весе» c_3 должен сохраняться, ибо направление проявления смысла «веса» c_3 () противоположно направлению проявления смысла c_2 (повиновению учителя авторитету). Знаки $c_4 < 0$ (должен быть минус. Матрица $Y_{m4} = Z_{m4} C_{44}$ модельных значений z_{kj} соответствует введенным z-, y-переменным $y_{ij} = c_{1j} * z_{i1} + c_{2j} * z_{i2} + c_{3j} * z_{i3} + c_{4j} * z_{i4}$ и параметрам c_{kj} (из матрицы C_{44}).

Постановка задачи. Заданы величины $16 = 4 * 4$ «весов» (из матрицы псевдосо собственных векторов C_{44} , соответствующей матрице собственных чисел $\Lambda_{44} = \text{diag}(4, 0, 0, 0)$ проявлений, вычисленных в системе из 4 смысловых уравнений с семантическими переменными $\text{смысл}(z_1), \dots, \text{смысл}(z_4)$. Требуется найти семантическое решение $\text{смысл}(y_1)$, используя системы многосмысловых уравнений, соответствующих СЛАУ $Y_{m4} = Z_{m4} C_{44}$, $C_{44} C_{44}^T = I_{44}$, $C_{44}^T C_{44} = I_{44}$ $\Lambda_{44} = \text{diag}(4, 0, 0, 0)$, $\lambda_1 = 4$, ограничениями $-1 < c_{11} < 0$, $-1 < c_{41} < 0$, и с управляющим параметром $c_{12} = 0.5000$.

Конструирование фраз смысла y-переменной в смысловом уравнении явления «субъективная самооценка студентом своих способностей, навыков, умений»

Для параметризации системы смысловых уравнений с семантическими переменными, $\text{смысл}(z_4)$, $\text{смысл}(z_2)$, $\text{смысл}(z_3)$, $\text{смысл}(z_4)$ используются элементы матрицы «весов» C_{44} . Смысловым уравнениям соответствуют числовые линейные уравнения (с неизвестными z-переменными, зависящих от наборов известных значений параметров c_{kj} k-ых y-переменных y_k , $k \in \{1, 2, 3, 4\}$), формализующих явление «субъективная самооценка студентом своих способностей, навыков, умений». Для формул z-переменных используются строки матрицы C_{44} (Таблица 1). Собственные числа $(4.000, 0.000, 0.000, 0.000)$ интерпретируются содержательно, они отображают объем информации, содержащейся в случайной k-ой y-

переменной.

$\text{смысл}(z_1) = 0,6132 * \text{смысл}(y_1) + 0,4561 * \text{смысл}(y_2) + 0,4561 * \text{смысл}(y_3) + 0,4561 * \text{смысл}(y_4);$
 $\text{смысл}(z_2) = 0,6905 * \text{смысл}(y_1) + 0,7233 * \text{смысл}(y_2);$
 $\text{смысл}(z_3) = 0,4973 * \text{смысл}(y_1) + 0,8676 * \text{смысл}(y_3);$
 $\text{смысл}(z_4) = 0,8757 * \text{смысл}(y_1) + 0,4829 * \text{смысл}(y_4).$
 $\text{смысл}(z_4).$

Система числовых линейных алгебраических уравнений (СЛАУ) после отбрасывания нулевых параметров) имеет вид:

$z_1 = 0,6132 * y_1 + 0,4561 * y_2 + 0,4561 * y_3 + 0,4561 * y_4;$

$z_2 = 0,6905 * y_1 + 0,7233 * y_2;$

$z_3 = 0,4973 * y_1 + 0,8676 * y_3;$

$z_4 = 0,8757 * y_1 + 0,4829 * y_4.$

Здесь z_1, z_2, z_3, z_4 – неизвестные z-переменные, вычисляемые (по формулам, содержащим как постоянные, так и случайные числа $Z_{m4} = (U_{m4} \Lambda_{44}^{1/2}) C_{44}^T$) и зависящие от случайных значений y-переменных из матрицы $Y_{m4} = U_{m4} \Lambda_{44}^{1/2}$ (Таблица 5), $\Lambda_{44} = \text{diag}(4, 0, 0, 0)$.

Элементы столбцов матрицы C_{44} являются параметрами при z-переменных дают обратную зависимость $Y_{m4} = Z_{m4} C_{44}$.

$y_1 = 0,8385 * z_1 + 0,1778 * z_2 + (-0,9491) * z_3 + (-0,9491) * z_4;$

$y_2 = 0,4561 * z_1 + 0,7233 * z_2; \text{disp}(y_2) = 0,0000;$

$y_3 = 0,4561 * z_1 + 0,4561 * z_3, \text{disp}(y_3) = 0,0000;$

$y_4 = 0,4561 * z_1 + 0,4829 * z_4.$

Первая формула определяет величину отклонения от нуля «субъективной самооценки студентом своих способностей, навыков, умений» по шкале стандартизованных z-изменчивостей.

Конструирование фраз смысла y-переменной в смысловом уравнении явления «субъективная самооценка студентом своих способностей, навыков, умений» начнем со смысла $\text{смысл}(z_4)$. Он имеет фразу, суммируемую из 2-х фраз: $\text{смысл}(z_4) = 0,8757 * \text{смысл}(y_1) + 0,4829 * \text{смысл}(y_4).$

Фраза имеет вид: $\text{смысл}(z_4) =$ «Иллюзии сохраняются (проявленные с силой $c_{41}^2 = 0,8757^2$) и после обучения немного (с силой $c_{44}^2 = 0,4829^2$) появляется у него способность осознать уровень своей прежней некомпетентности».

$\text{Смысл}(z_3)$ имеет фразу, суммируемую из 2-х фраз: $\text{смысл}(z_3) = 0,4973 * \text{смысл}(y_1) + 0,8676 * \text{смысл}(y_3).$ Фраза имеет вид: $\text{смысл}(z_3) =$ «Иллюзии у студента сохраняются (проявленные с силой $c_{13}^2 = 0,4973^2$, а его не способность осознать всю глубину своей некомпетентности более сильна (с силой $c_{33}^2 = 0,8676^2$).

$\text{Смысл}(z_2)$ имеет фразу, суммируемую из 2-х фраз. Фраза имеет вид: $\text{смысл}(z_2) = 0,6905 * \text{смысл}(y_1) + 0,7233 * \text{смысл}(y_2).$ Фраза

$\text{смысла}(z_2) =$ «Иллюзии студента сохраняются (проявленные с силой $= 0,6905^2$) и сохраняется (с силой $= 0,7233^2$) не способность адекватно оценивать действительно высокий уровень умений, навыков у других».

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Смысл(z_1) имеет фразу, суммируемую 4 фразы (проявляемых с силами 4-х у-переменных из уравнения): $\text{смысл}(z_1) = \langle \text{Иллюзии у студента сохраняются (проявленные с силой } c_{11}^2=0,6132, \text{ если проявляются факторы : а) с смыслом}(y_2) - \text{с силой } c_{21}^2=0,4561^2; \text{ б) с смыслом}(y_3) - \text{с силой } c_{31}^2=0,4561^2, \text{ в) с смыслом}(y_4) - \text{с силой } c_{41}^2=0,4561^2 \rangle$. Смысловые уравнения (8 штук) позволяют извлечь относительно новые знания, обоснованные числовыми данными. Для ИИ представляет интерес фраза нового смысла у-переменной y_1 .

Новый смысл(y_1) конструируется как сумма вновь полученных z-смыслов из смыслового уравнения

$$\text{смысл}(y_1) = 0,8385 * \text{смысл}(z_1) + 0,1778 * \text{смысл}(z_2) + (-0,9491) * \text{смысл}(z_3) + (-0,9491) * \text{смысл}(z_4).$$

Оптимизм внушает следующее извлеченное знание: фраза нового смысла(y_1) содержит слова – с силой $(0,9491)^2$ уменьшает «его неспособность осознавать всю глубину своей некомпетентности более сильна» и «после обучения очень сильно появляется у него способность осознать уровень своей прежней некомпетентности». Этим знанием модель предполагает в будущем возвращение к правильной оценке своих способностей, навыков, умений. Модель проявила прогнозную способность.

Выше мы опирались на элементы теории разговорного языка искусственного интеллекта [16-33] популярен «принцип линейного мышления». Числовым уравнениям из СЛАУ соответствует матричное смысловое равенство вида $\text{смысл}(Y_{m4}) = \text{смысл}(Z_{m4}C_{44})$, где $\text{смысл}(Z_{m4}) = \text{смысл}(z_1) \oplus \dots \oplus \text{смысл}(z_4)$, $\text{смысл}(Z_{m4}C_{44}) = \text{смысл}(Z_{m4}C_1) \oplus \dots \oplus \text{смысл}(Z_{m4}C_4)$, $C_1, \dots, C_4$ – псевдосообственные векторы. Линейное числовое равенство соответствует фразам смыслов каждой переменной, а сумма фраз смыслов семантических переменных $\text{смысл}(z_1) \oplus \text{смысл}(z_2) \oplus \text{смысл}(z_3) \oplus \text{смысл}(z_4)$

должна соответствовать их суммарной фразе ($\text{смысл}(y)$) без когнитивного диссонанса. смысловому линейному конструированию многосмысловых линейных уравнений, где линейность выражена через слагаемые фразы, образующую новую осмысленную фразу. Подставим в равенство $Y_{m4} = Z_{m4}C_{44}$ значения элементов матрицы C_{44} (Таблица 1). В теории разговорного языка искусственного интеллекта [3,4] популярен «принцип линейного мышления». Матричное смысловое равенство вида $\text{смысл}(Y_{m4}) = \text{смысл}(Z_{m4}C_{44})$, где $\text{смысл}(Z_{m4}) = \text{смысл}(z_1) \oplus \dots \oplus \text{смысл}(z_4)$, $\text{смысл}(Z_{m4}C_{44}) = \text{смысл}(Z_{m4}C_1) \oplus \dots \oplus \text{смысл}(Z_{m4}C_4)$ точно соответствует смысловому равенству и линейному числовому равенству $Y_{m4} = Z_{m4}C_{44}$. Линейное числовое равенство удовлетворяет

смысловому линейному конструированию многосмысловых линейных уравнений, где линейность выражена через слагаемые фразы, образующую новую осмысленную фразу. Подставим в равенство $Y_{m4} = Z_{m4}C_{44}$ значения элементов матрицы C_{44} (Таблица 1). Система независимых смысловых уравнений $\text{смысл}(y_1) = 0,8530 * \text{смысл}(z_1) + 1,0000 * \text{смысл}(z_2) + 1,0000 * \text{смысл}(z_3) + 1,0000 * \text{смысл}(z_4);$ $\text{смысл}(y_2) = 0,5000 * \text{смысл}(z_1);$ $\text{смысл}(y_3) = -0,1057 * \text{смысл}(z_1);$ $\text{смысл}(y_4) = (-0,1057) * \text{смысл}(z_1).$

Для ясности восприятия шагов извлечения знаний из смысловых равенств заметим: в модели выполнены ограничения (смотрите раздел Оптимизационная Задача) на знаки 8 значений параметров из матрицы C_{44} . Из этих ограничений для ИИ важны формулы $c_{1j}^2 + c_{2j}^2 + c_{3j}^2 + c_{4j}^2 = 1$, $c_{11}^2 + c_{12}^2 + c_{13}^2 + c_{14}^2 \neq 1$, $j=1, \dots, 4$, $c_{12}=0,5$ – управляющий параметр. Для j-ой у-переменной значения весов $c_{1j}^2, c_{2j}^2, c_{3j}^2, c_{4j}^2$ (могут иметь значения, близкие к 1) «измеряют» силы проявлений с изменчивостями $z_{11}, z_{12}, z_{13}, z_{14}$, каждое слагаемое в формуле у-переменной имеет вид произведения $c_{kj} * z_{ik}$ (отклонение z_{ik} от 0 k-ой z-переменной, присущее «весу» c_{kj}). Квадраты значений «весов» $c_{1j}, c_{2j}, c_{3j}, c_{4j}$ интерпретируются как веса (доли целого) $c_{1j}^2, c_{2j}^2, c_{3j}^2, c_{4j}^2$, равные 4 силам проявлений каждого k-го z-фактора. Сумма $c_{1j}^2, c_{2j}^2, c_{3j}^2, c_{4j}^2$ не равна 1, так как в столбцах матрицы C_{44} расположены взаимно ортогональные векторы, неединичных длин. Это – алгебраическое обоснование модельных ограничений: $C_{44}C_{44}^T = I_{44}$, $C_{44}^T C_{44} \neq I_{44}$, $\Lambda_{44} = \text{diag}(\lambda_1, \dots, \lambda_4) = \text{diag}(4, 0, 0, 0)$. Наборы из 4 весов измеряют силы проявлений в j-той у-переменной (с нулевой дисперсией): $c_{1j}^2 + c_{2j}^2 + c_{3j}^2 + c_{4j}^2 = 1$, $\text{disp}(y_j) = 0$, $j=2, \dots, 4$. Нулевая дисперсия у-переменной означает неизменность значений у-переменной при постоянных значениях $(c_{1j}, c_{2j}, c_{3j}, c_{4j})$. Постоянные значения «весов» $(c_{1j}, c_{2j}, c_{3j}, c_{4j})$ могут иметь ненулевую ($y_{i1} * c_{j1} \neq 0$, $y_{i1} \neq 0$, $i=1, \dots, 30$) или нулевую ($y_{ij} * c_{kj} = 0$, $j=2, \dots, 4$, $y_{ij} = 0$, $k=1, \dots, 4$, $i=1, \dots, 30$) у-изменчивость, но z-изменчивости всегда ненулевые, так как значение z_{ik} равно линейной комбинации элементов i-ой строки (где 1-ый ее элемент ненулевой) умножается на ненулевое значение «веса». Поэтому в ненулевые значения в столбца №1 из Таблицы 5 преобразуются в ненулевые элементы всех столбцов матрицы Z_{m4} (Таблица 6).

Так как $c_{11}^2 + c_{12}^2 + c_{13}^2 + c_{14}^2 = 1$, то равенства $c_{11}^2 = 0,6132^2$, $c_{12}^2 = 0,4561^2$, $c_{13}^2 = 0,4561^2$, $c_{14}^2 = 0,4561^2$ соответствуют неодинаковым долям силам проявлений у-факторов y_1, y_2, y_3, y_4 . Но доля каждого z-фактора z_2, z_3, z_4 сильнее проявлена в величине «субъективная самооценка студентом своих способностей, навыков, умений», чем доля фактора y_1 , равная $c_{11}^2 = 0,6132^2$. По силе влияния фактор y_1 относится к интервалу «заметная» -

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$c_{11}^2=0,6132^2$ (0,5 – 0,7]. Динамика значений субъективных оценок влияющих факторов (они равны из-за однофакторности модели: $\Lambda_{44}=\text{diag}(4,0,0,0)$) $c_{21}^*z_{i2}=c_{31}^*z_{i3}=c_{41}^*z_{i4}$, $i=1,\dots, 25$, за 25 занятий имеет динамику. Для 4-факторной модели этих равенств не будет. Значения «весов» для факторов y_2, y_3, y_4 относится к интервалу «высокая» (0,5 – 0,7] по шкале Чеддока.

Моделирование числовых матриц Y_{m4} , Z_{m4} у- и z-переменных для системы из 4 многосмысловых уравнений

Матрица $Y_{m4}=Z_{m4}C_{44}$ модельных значений z_{kj} соответствует введенным z-, у-переменным $y_{ij}=c_{1j}^*z_{i1}+c_{2j}^*z_{i2}+c_{3j}^*z_{i3}+c_{4j}^*z_{i4}$ и параметрам c_{kj} (из матрицы C_{44}). Первая у-переменная моделирует проявления y_1 , соответствующие величине степени, остальные у-переменные y_2, y_3, y_4 будут интерпретированы, найдены их смыслы. Эта модель допускает существование скрытых 3-х у-факторов с нулевыми дисперсиями в математической числовой модели, где отдельно моделировались матрицы U_{m4} (из матрицы равномерно распределенных случайных чисел V_{m4}^0 (Таблица 3)) и Y_{m4} [17] такие, что

$(1/m)U_{m4}^T U_{m4}=I_{44}$ (Таблица 4), $Y_{m4}=U_{m4}\Lambda^{1/2}_{44}$ (Таблица 5), $\Lambda_{44}=\text{diag}(4,0,0,0)$, затем моделировалась матрица $Z_{m4}=Y_{m4}C_{44}^T$ (Таблица 6). Матрица значений z-переменных z_1, z_2, z_3, z_4 $Z_{m4}=Y_{m4}C_{44}^T$, $C_{44}^T C_{44}=I_{44}$, $C_{44}C_{44}^T=I_{44}$. Матрицы Z_{m4} и Y_{m4} содержат модельные значения изменчивостей (отклонений от 0), соответствующих реальным z-факторам эксперимента. Матрица $Y_{m4}^{(t)}$ $t=1,\dots,\infty$, обеспечивает случайность значений у- и z-отклонений из матриц $(Y_{m4}^{(t)}, Z_{m4}^{(t)})$. В матрице Y_{m4} элементы 1-го столбца $y_{1j}, y_{21}, \dots, y_{m1}$ (j-ая у-переменная имеет не нулевые значения, столбцы с номерами $j=2,3,4$ имеют нулевые значения, ибо $\Lambda_{44}=\text{diag}(4,0,0,0)$). Все столбцы матрицы $Y_{m4}=U_{m4}\Lambda^{1/2}_{44}$ (Таблица 5) имеют среднее арифметическое, равное нулю: $(1/m)(y_{1j}+y_{2j}+\dots+y_{mj})=0$, дисперсию равную λ_j : $(1/m)(y_{1j}^2+y_{2j}^2+\dots+y_{mj}^2)=\lambda_j$, $j=1,\dots,4$, при этом сумма дисперсий равна 4: $\lambda_1+\dots+\lambda_4=4$. Матрицы Z_{m4} , Y_{m4} приведены в Таблицах 5 и 6.

Таблица 1. Модельная матрица C_{44} псевдособственных векторов для матрицы собственных чисел $\Lambda_{44}=\text{diag}(4,0,0,0)$, полученная таблицы-программы Оптимизационной задачи: $(I_{44}, I_{44})=>(C_{44}, \Lambda_{44})$

c_1	c_2	c_3	c_4	Сумма квадратов
0,6132	0,4561	0,4561	0,4561	1,0000
0,6905	0,7233	0,0000	0,0000	1,0000
0,4973	0,0000	0,8676	0,0000	1,0000
0,8757	0,0000	0,0000	0,4829	1,0000
1,8670	0,7312	0,9607	0,4411	4,0000

Таблица 2. Начальные значения элементов матрицы C_{44} до решения Оптимизационной Задачи $(I_{44}, \Lambda_{44})=>(C_{44}, \Lambda_{44})$

	1	2	3	4	
z_1	1,0000	0,0000	0,0000	0,0000	1,0000
z_2	0,0000	1,0000	0,0000	0,0000	1,0000
z_3	0,0000	0,0000	1,0000	0,0000	1,0000
z_4	0,0000	0,0000	0,0000	1,0000	1,0000
	1,0000	1,0000	1,0000	1,0000	4,0000
$c_{12}^2=$	0,5000				

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Поиск решения

Установить целевую ячейку:

Равной: ☒ максимальному значению ☐ значению:

☐ минимальному значению

Изменяя ячейки:

Предположить

Ограничения:

Добавить
Изменить
Удалить

Выполнить
Закрыть
Параметры
Восстановить
Справка

Рисунок 1. Вид таблицы-программы Оптимизационной задачи: $(I_{44}, \Lambda_{44}) \Rightarrow (C_{44}, \Lambda_{44})$ в модели с 4 z-переменными, 4 y-переменными

Результаты поиска решения

Решение найдено. Все ограничения и условия оптимальности выполнены.

Тип отчета

☒ Сохранить найденное решение
☐ Восстановить исходные значения

Результаты
Устойчивость
Пределы

OK Отмена Сохранить сценарий... Справка

Рисунок 2. Вид таблицы-программы Оптимизационной задачи: $(I_{44}, \Lambda_{44}) \Rightarrow (C_{44}, \Lambda_{44})$ в модели с 4 z-переменными, 4 y-переменными

Таблица 3. Матрица V^0_{m4} значений равномерно распределенных в интервале $[-1;1]$ случайных чисел

№	v^0_1	v^0_2	v^0_3	v^0_4
№	1	2	3	4
1	-0,698355	0,10910367	0,769829	0,580553606
2	-0,356059	0,3447676	-0,56462	0,985900449
3	-0,336467	-0,744499	-0,23234	0,877681814
4	-0,923765	0,49143956	-0,57726	0,468245491
5	0,703116	0,21561327	-0,96649	-0,507187109
6	-0,562853	0,45298624	-0,58696	-0,150608844
7	-0,426069	-0,6508072	0,027253	0,429853206
8	-0,4326	-0,8472854	0,30015	-0,544663839
9	0,274514	-0,2687765	0,31315	0,628040407
10	-0,249794	0,43626209	0,461653	0,411236915
11	0,656056	0,12808618	0,630848	0,751762444
12	-0,655751	0,17270425	0,454085	0,55528428

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13	0,680471	0,22458571	-0,78484	0,229102451
14	-0,333415	-0,3935362	0,958251	0,602893155
15	-0,072054	0,10019227	-0,63341	0,54136784
16	0,125217	0,95892209	-0,02561	0,560716575
17	0,355083	-0,0442824	0,271828	0,761650441
18	-0,398053	-0,7206336	-0,73199	0,390850551
19	0,302347	0,08999908	-0,92651	-0,655629139
20	-0,914487	0,54765465	0,064425	0,924680319
21	-0,247902	-0,8737754	0,191198	0,163975951
22	-0,446089	0,02462844	-0,00534	-0,973021638
23	0,836482	0,48857082	-0,1088	0,80425428
24	-0,892392	0,85448775	-0,70952	-0,989867855
25	-0,405255	-0,8711509	0,107212	-0,90295114
	-0,1767	0,0090	-0,0922	0,2378
	0,2995	0,2834	0,3022	0,4382

Таблица 4. Матрица U_{m4} u-изменчивостей

№	u_1	u_2	u_3	u_4
1	-1,0071	0,1881	1,5905	0,5549
2	-0,3463	0,6308	-0,8718	1,2111
3	-0,3084	-1,4157	-0,2587	1,0359
4	-1,4424	0,9064	-0,8951	0,3731
5	1,6988	0,3882	-1,6133	-1,2059
6	-0,7455	0,8341	-0,9130	-0,6287
7	-0,4814	-1,2397	0,2203	0,3109
8	-0,4940	-1,6088	0,7239	-1,2666
9	0,8712	-0,5219	0,7479	0,6318
10	-0,1411	0,8027	1,0219	0,2808
11	1,6079	0,2237	1,3341	0,8320
12	-0,9249	0,3075	1,0079	0,5140
13	1,6550	0,4050	-1,2781	-0,0140
14	-0,3025	-0,7563	1,9382	0,5911
15	0,2021	0,1713	-0,9987	0,4915
16	0,5830	1,7847	0,1228	0,5228
17	1,0268	-0,1001	0,6716	0,8480
18	-0,4273	-1,3708	-1,1806	0,2478
19	0,9250	0,1522	-1,5395	-1,4462
20	-1,4244	1,0120	0,2889	1,1120
21	-0,1374	-1,6586	0,5228	-0,1194
22	-0,5201	0,0293	0,1602	-1,9600
23	1,9563	0,9010	-0,0307	0,9170
24	-1,3818	1,5885	-1,1392	-1,9872

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	GIF (Australia)	= 0.564	ESJI (KZ)	= 8.100	IBI (India)	= 4.260
	JIF	= 1.500	SJIF (Morocco)	= 6.004	OAJI (USA)	= 0.350

25	-0,4412	-1,6536	0,3679	-1,8465
	0,0000	0,0000	0,0000	0,0000
	1,0000	1,0000	1,0000	1,0000

Таблица 5. Матрица Y_{m4} у–изменчивостей

№	y_1	y_2	y_3	y_4
1	-2,014288	0,0000	0,0000	0,0000
2	-0,69251	0,0000	0,0000	0,0000
3	-0,616852	0,0000	0,0000	0,0000
4	-2,88471	0,0000	0,0000	0,0000
5	3,397508	0,0000	0,0000	0,0000
6	-1,491045	0,0000	0,0000	0,0000
7	-0,962852	0,0000	0,0000	0,0000
8	-0,988072	0,0000	0,0000	0,0000
9	1,742456	0,0000	0,0000	0,0000
10	-0,282165	0,0000	0,0000	0,0000
11	3,215787	0,0000	0,0000	0,0000
12	-1,849773	0,0000	0,0000	0,0000
13	3,310065	0,0000	0,0000	0,0000
14	-0,605067	0,0000	0,0000	0,0000
15	0,404179	0,0000	0,0000	0,0000
16	1,165946	0,0000	0,0000	0,0000
17	2,053574	0,0000	0,0000	0,0000
18	-0,854668	0,0000	0,0000	0,0000
19	1,849933	0,0000	0,0000	0,0000
20	-2,848885	0,0000	0,0000	0,0000
21	-0,274858	0,0000	0,0000	0,0000
22	-1,04016	0,0000	0,0000	0,0000
23	3,912502	0,0000	0,0000	0,0000
24	-2,763563	0,0000	0,0000	0,0000
25	-0,88248	0,0000	0,0000	0,0000
	0,0000	0,0000	0,0000	0,0000
	4,0000	0,0000	0,0000	0,0000

Таблица 6. Матрица Z_{m4} z–изменчивостей

№	z_1	z_2	z_3	z_4
1	-1,2352	-1,3909	-1,0017	-1,7639
2	-0,4246	-0,4782	-0,3444	-0,6064
3	-0,3783	-0,4259	-0,3068	-0,5402
4	-1,7689	-1,9919	-1,4346	-2,5261
5	2,0834	2,3460	1,6896	2,9752

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	JIF = 1.500	SJIF (Morocco) = 6.004	OAJI (USA) = 0.350

6	-0,9143	-1,0296	-0,7415	-1,3057
7	-0,5904	-0,6648	-0,4788	-0,8432
8	-0,6059	-0,6823	-0,4914	-0,8653
9	1,0685	1,2032	0,8665	1,5259
10	-0,1730	-0,1948	-0,1403	-0,2471
11	1,9719	2,2205	1,5992	2,8161
12	-1,1343	-1,2773	-0,9199	-1,6198
13	2,0297	2,2856	1,6461	2,8986
14	-0,3710	-0,4178	-0,3009	-0,5299
15	0,2478	0,2791	0,2010	0,3539
16	0,7150	0,8051	0,5798	1,0210
17	1,2593	1,4180	1,0212	1,7983
18	-0,5241	-0,5901	-0,4250	-0,7484
19	1,1344	1,2774	0,9200	1,6200
20	-1,7469	-1,9672	-1,4168	-2,4948
21	-0,1685	-0,1898	-0,1367	-0,2407
22	-0,6378	-0,7182	-0,5173	-0,9109
23	2,3991	2,7016	1,9457	3,4262
24	-1,6946	-1,9082	-1,3743	-2,4201
25	-0,5411	-0,6094	-0,4389	-0,7728
	0,0000	0,0000	0,0000	0,0000
	1,5041	1,9072	0,9892	3,0674

Таблица 7. Упорядоченные по убыванию значений сил степени утомления $c_3 \cdot z_{31}$, уменьшающиеся силы проявлений факторов $c_1 \cdot z_1$, $c_2 \cdot z_2$, $c_3 \cdot z_3$ в течение 25 практических занятий на компьютере

y_1	$c_1 \cdot z_1$	$c_2 \cdot z_2$	$c_3 \cdot z_3$	$c_4 \cdot z_4$	№
-2,8847	-0,7574011	-0,6343	-0,8045	-0,8045	4
-2,8489	-0,2603936	-0,2181	-0,2766	-0,2766	20
-2,7636	-0,2319451	-0,1943	-0,2464	-0,2464	24
-2,0143	-1,0846922	-0,9084	-1,1521	-1,1521	1
-1,8498	1,2775113	1,0699	1,3569	1,3569	12
-1,4910	-0,5606542	-0,4695	-0,5955	-0,5955	6
-1,0402	-0,3620462	-0,3032	-0,3845	-0,3845	22
-0,9881	-0,371529	-0,3112	-0,3946	-0,3946	8
-0,9629	0,6551884	0,5487	0,6959	0,6959	7
-0,8825	-0,106098	-0,0889	-0,1127	-0,1127	25
-0,8547	1,2091816	1,0127	1,2843	1,2843	18
-0,6925	-0,695541	-0,5825	-0,7388	-0,7388	2
-0,6169	1,2446315	1,0424	1,3220	1,3220	3
-0,6051	-0,2275139	-0,1905	-0,2416	-0,2416	14
-0,2822	0,1519772	0,1273	0,1614	0,1614	10
-0,2749	0,4384123	0,3672	0,4657	0,4657	21
0,4042	0,7721731	0,6467	0,8201	0,8201	15

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1,1659	-0,3213674	-0,2691	-0,3413	-0,3413	16
1,7425	0,6956013	0,5826	0,7388	0,7388	9
1,8499	-1,0712213	-0,8972	-1,1378	-1,1378	19
2,0536	-0,1033506	-0,0866	-0,1098	-0,1098	17
3,2158	-0,3911151	-0,3276	-0,4154	-0,4154	11
3,3101	1,4711563	1,2321	1,5626	1,5626	13
3,3975	-1,0391391	-0,8703	-1,1037	-1,1037	5
3,9125	-0,3318252	-0,2779	-0,3524	-0,3524	23

Заклучение

Проведена формализация процесса «влияние на степень субъективной самооценки студентом своих способностей, навыков, умений. Введенные параметры, переменные численно измеряют, показывают во сколько раз проявления одного фактора больше/меньше проявления другого фактора. Это позволило вычислить все модельные силы проявлений субъективной самооценки студентом своих способностей, навыков, умений» и оценить однодневные величины степени оценки за 25 дней. Выражены численно в виде линейной комбинации значений $16=4*4$ параметров при неизвестных 4-х z-переменных, выделена только 1 линейная комбинация, равная y-переменной y_1 . В ней используются 4 y-переменные и найдена формула оценки. Найдены модельные отклонения параметров $z_{i1}*c_{k1}$ (k-го фактора проявления (из 4), в i-ом практикуме, отдельно моделировались матрицы $U_{m4}(\text{rang}(U_{m4})=4)$ и $Y_{m4}(\text{rang}(Y_{m4})=1)$ такие, что $(1/m)U_{m4}^T U_{m4}=I_{44}$, $Y_{m4}=U_{m4}\Lambda^{1/2}_{44}$, $Z_{m4}=Y_{m4}C_{44}^T$ ($\text{rang}(Z_{m4})=4$). Матрица значений z-переменных z_1, z_2, z_3, z_4 $Z_{m4}=Y_{m4}C_{44}^T$, имеет ковариационную, а не корреляционную матрицу, ибо ее псевдосообственные векторы удовлетворяют соотношениям $C_{44}^T C_{44} \neq I_{44}$, $C_{44} C_{44}^T = I_{44}$. Разработана система многосмысловых

уравнений с 4 семантическими неизвестными переменными, найдено одно ее решение в виде фразы из сложносочиненного предложения. Выведена формула величины степени субъективной самооценки студентом своих способностей, навыков, умений: $y_1=0,8385*z_1+0,1778*z_2+(-0,9491)*z_3+(-0,9491)*z_4$. Новый смысл(y_1) конструируется как сумма вновь полученных z-смыслов из смыслового уравнения $\text{смысл}(y_1)=0,8385*\text{смысл}(z_1)+0,1778*\text{смысл}(z_2)+(-0,9491)*\text{смысл}(z_3)+(-0,9491)*\text{смысл}(z_4)$. Оптимизм внушает следующее извлеченное знание: фраза нового смысла(y_1) содержит слова – с силой $(0,9491)^2$ уменьшает «его неспособность осознавать всю глубину своей некомпетентности более сильна» и «после обучения очень сильно появляется у него способность осознать уровень своей прежней некомпетентности». Этим знанием модель предполагает в будущем возвращение к правильной оценке своих способностей, навыков, умений. Модель проявила прогнозную способность.

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ECONOMIC EFFICIENCY OF CRM SYSTEMS IMPLEMENTATION

Abstract: The purpose of the article is to assess the economic efficiency of implementing CRM systems using the example of the international company Samsung and the national supermarket chain Korzinka. The methodological basis consists of comparative analysis, systematization, generalization and case analysis, supplemented by a system of quantitative and qualitative indicators (ROI, CAC, CLV, Customer Retention Rate, Conversion Rate). According to the results of the study, the global CRM systems market will grow to \$163.16 billion. By 2030, with an average annual growth rate of 14.6%, CRM remains the largest segment of the global enterprise software market. The case analysis showed that the Korzinka network's comparable sales increased by 9.3% (to 9.4 trillion soums), the revenue of the Korzinka Go online service increased by 188%, and the active audience of the loyalty program reached 1.8 million people; Samsung's implementation of personalized digital solutions is accompanied by an increase in the average receipt by 35% and retention of 68% of clients for more than five years. The scientific novelty of the work is to compare the economic effect of CRM for companies of various scales — a multinational corporation and a national retailer — in the context of the digital transformation of the Uzbek economy. The practical significance of the results lies in the possibility of using the presented indicator system when selecting and evaluating the effectiveness of CRM solutions by domestic enterprises.

Key words: CRM system, economic efficiency, digital transformation, customer loyalty, performance indicators, case analysis, digital economy.

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ЭКОНОМИЧЕСКАЯ ЭФФЕКТИВНОСТЬ ВНЕДРЕНИЯ CRM-СИСТЕМ

Аннотация: Цель статьи состоит в оценке экономической эффективности внедрения CRM-систем на примере международной компании Samsung и национальной сети супермаркетов Korzinka. Методологическую основу составляют сравнительный анализ, систематизация, обобщение и кейс-анализ, дополненные системой количественных и качественных показателей (ROI, CAC, CLV, Customer Retention Rate, Conversion Rate). По результатам исследования установлено, что мировой рынок CRM-систем вырастет до 163,16 млрд долл. США к 2030 году при среднегодовом темпе роста 14,6%, а CRM остаётся крупнейшим сегментом мирового рынка корпоративного программного обеспечения. Кейс-анализ показал, что у сети Korzinka сопоставимые продажи выросли на 9,3% (до 9,4 трлн сум), выручка онлайн-сервиса Korzinka Go — на 188%, а активная аудитория программы лояльности достигла 1,8 млн человек; у компании Samsung внедрение персонализированных цифровых решений сопровождается ростом среднего чека на 35% и удержанием 68% клиентов на протяжении более пяти лет. Научная новизна работы заключается в сопоставлении экономического эффекта CRM у компаний различного масштаба — многонациональной

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корпорации и национального ритейлера — в условиях цифровой трансформации экономики Узбекистана. Практическая значимость результатов состоит в возможности использования представленной системы показателей при выборе и оценке эффективности CRM-решений отечественными предприятиями.

Ключевые слова: CRM-система, экономическая эффективность, цифровая трансформация, клиентская лояльность, показатели эффективности, кейс-анализ, цифровая экономика.

Введение

Актуальность исследования усиливается тем, что развитие цифровой экономики закреплено на уровне нормативно-правовых документов Республики Узбекистан. Закон Республики Узбекистан от 11.12.2003 г. № 560-II «Об информатизации» формирует правовую основу использования информационных ресурсов и информационных систем субъектами предпринимательства [1]. Указ Президента Республики Узбекистан от 24.05.2023 г. № УП-76 «О мерах по эффективной организации государственного управления в сфере цифровых технологий в рамках административных реформ» определяет основные направления цифровой трансформации сфер, отраслей и регионов, стимулируя внедрение современных информационных технологий в деятельность предприятий [2]. Институциональная среда, ориентированная на цифровизацию бизнес-процессов, формирует основу для оценки экономической эффективности внедрения цифровых инструментов управления клиентами в компаниях различного масштаба.

Одним из наиболее востребованных инструментов цифровой трансформации являются системы Customer Relationship Management (CRM), обеспечивающие централизованное хранение и анализ клиентских данных, автоматизацию продаж и маркетинга, а также поддержку управленческих решений. Практическая значимость CRM подтверждается устойчивым ростом мирового рынка: по данным Grand View Research, к 2030 году его объём превысит 163 млрд долл. США при среднегодовом темпе роста около 14,6% [3], а по данным Gartner, CRM остаётся крупнейшим сегментом мирового рынка корпоративного программного обеспечения [4]. Вместе с тем большинство исследований рассматривает CRM преимущественно как инструмент автоматизации маркетинга и продаж, тогда как влияние данных систем на удержание клиентов, операционные издержки и развитие цифровых каналов продаж требует более развёрнутого сопоставительного анализа на примере компаний разного масштаба.

Объектом исследования является экономическая эффективность внедрения CRM-систем, предметом — количественные и качественные показатели этой эффективности у компаний различного масштаба и сферы деятельности. Цель статьи состоит в оценке экономической эффективности внедрения CRM-

систем на примере международной компании Samsung и национальной сети супермаркетов Korzinka.

Для достижения цели поставлены следующие задачи: систематизировать теоретические подходы к пониманию CRM как инструмента цифровой трансформации; сформировать систему количественных и качественных показателей оценки экономической эффективности CRM; провести сопоставительный кейс-анализ практики внедрения CRM в компаниях Samsung и Korzinka; сформулировать выводы и практические рекомендации. Исследовательская гипотеза состоит в том, что экономическая эффективность внедрения CRM определяется не только ростом объёма продаж, но и комплексным влиянием на удержание клиентов, снижение операционных издержек и развитие цифровых каналов взаимодействия с потребителями.

Обзор литературы

Анализ научной литературы показывает, что подходы к пониманию CRM существенно эволюционировали. Если первоначально CRM рассматривалась преимущественно как средство автоматизации взаимодействия с клиентами, то современные исследователи определяют её как комплексную стратегию управления. Ф. Котлер и К. Келлер отмечают, что построение долгосрочных отношений с клиентами является важнейшим фактором конкурентоспособности предприятия и центральным элементом маркетинга взаимоотношений [5]. А. Пейн рассматривает CRM как целостный стратегический подход, объединяющий маркетинг, продажи, обслуживание клиентов и информационные технологии для повышения акционерной стоимости компании за счёт выстраивания долгосрочных, прибыльных отношений с потребителями [6].

Современные аналитические источники уделяют особое внимание месту CRM в структуре корпоративного программного обеспечения. По данным Gartner, в 2023 году CRM оставался крупнейшим сегментом мирового рынка корпоративного ПО с долей 13,6%, опережая рынки СУБД (13,1%) и программного обеспечения безопасности (10,4%) [4]. Это подтверждает не только устойчивый спрос на CRM-решения, но и их растущую роль в общей архитектуре цифровизации предприятий.

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Таким образом, существующие исследования формируют прочную теоретическую основу для изучения CRM-систем: от концептуального определения (Котлер, Келлер), через стратегическую модель управления взаимоотношениями (Пейн), до количественных данных о масштабах рынка (Gartner, Grand View Research). Вместе с тем комплексная оценка экономической эффективности CRM с учётом сопоставления компаний разного масштаба — многонациональной корпорации и национального ритейлера — остаётся недостаточно разработанной, что обуславливает выбор методов настоящего исследования.

Методология

Исследование основано на анализе научной литературы, нормативно-правовых документов,

аналитических отчётов и статистических данных, посвящённых внедрению CRM-систем. В работе использованы методы сравнительного анализа, систематизации, обобщения и кейс-анализа, что позволило оценить экономическую эффективность применения CRM на примере компании Samsung и сети супермаркетов Korzinka.

Для оценки экономической эффективности внедрения CRM-систем применяется совокупность количественных и качественных показателей, позволяющих определить влияние CRM на финансовые результаты, эффективность бизнес-процессов и качество взаимодействия с клиентами. Основные из них представлены в таблице 1.

Таблица 1. Основные показатели оценки экономической эффективности внедрения CRM-систем

Показатель	Экономическое содержание	Влияние внедрения CRM
ROI	Окупаемость инвестиций	Рост прибыли от внедрения
CAC	Стоимость привлечения клиента	Снижение затрат на привлечение клиентов
CLV (LTV)	Пожизненная ценность клиента	Рост дохода от постоянных клиентов
Customer Retention Rate	Коэффициент удержания клиентов	Повышение лояльности клиентов
Conversion Rate	Конверсия продаж	Увеличение количества успешных сделок

Источник: разработано авторами на основе [5; 6].

Выбор компаний Samsung и Korzinka для кейс-анализа обусловлен необходимостью сопоставить экономические эффекты внедрения CRM в организациях разного масштаба и сферы деятельности: многонациональной корпорации с многолетней историей цифровизации клиентских сервисов и национальной розничной сети, активно наращивающей цифровые каналы продаж на рынке Узбекистана. Данные по компании Korzinka взяты из официального годового отчёта сети за 2024 год [7; 8], данные по компании Samsung — из открытых аналитических материалов о её маркетинговой и клиентской стратегии [9].

Результаты

Экономическая эффективность внедрения CRM-систем определяется не только ростом объёма продаж, но и комплексным влиянием на финансовые и организационные результаты деятельности предприятия. Использование CRM способствует оптимизации бизнес-процессов, повышению качества обслуживания клиентов, сокращению операционных затрат и увеличению доходов компании за счёт более эффективного управления взаимоотношениями с потребителями.

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Рисунок 1. Динамика мирового рынка CRM-систем (2023–2030 гг.), млрд долл. США [3]

Как видно из рисунка 1, мировой рынок CRM-систем демонстрирует устойчивую положительную динамику. По прогнозам Grand View Research, к 2030 году его объём превысит 163 млрд долл. США при среднегодовом темпе роста около 14,6% [3]. Это свидетельствует о возрастающей востребованности CRM-систем как одного из ключевых инструментов цифровой трансформации бизнеса и повышения эффективности управления предприятиями.

Представленные в таблице 1 показатели позволяют комплексно оценить экономическую

эффективность внедрения CRM-систем. Вместе с тем наиболее объективные результаты можно получить при анализе практического опыта компаний, успешно внедривших данные технологии. В связи с этим далее рассматриваются результаты применения CRM-систем на примере международной компании Samsung и отечественной сети супермаркетов Korzinka, что позволяет сопоставить особенности и экономические эффекты их использования в организациях различного масштаба и сферы деятельности (табл. 2).

Таблица 2. Сравнительная оценка результатов внедрения CRM-систем в компаниях Samsung и Korzinka

Показатель	Samsung	Korzinka	Экономический эффект
Рост цифровых продаж	Средний чек +35% (AI-платформа Shop Samsung)	Выручка Korzinka Go +188%	Развитие цифровых каналов продаж
Сопоставимые продажи / оборот	—	+9,3% (оборот — 9,4 трлн сум)	Рост выручки сети
Удержание клиентов	68% клиентов — свыше 5 лет	1,8 млн активных участников программы лояльности	Повышение клиентской лояльности
Снижение издержек обслуживания	92% обращений решает Vixby без сотрудников	—	Снижение операционных затрат

Источник: разработано авторами на основе годового отчёта Korzinka за 2024 год [7; 8] и открытых аналитических материалов о клиентской стратегии Samsung [9].

По данным годового отчёта Korzinka за 2024 год, сопоставимые продажи супермаркетов и магазинов формата Mahalla выросли на 9,3%, а общий оборот сети достиг рекордных 9,4 трлн сум [7]. Наибольший рост показал онлайн-сервис Korzinka Go, выручка которого увеличилась на 188% на фоне модернизации операционной деятельности сервиса и роста доли онлайн-продаж

в Ташкентском регионе [7]. Программа лояльности Korzinka Plus объединяет 1,8 млн активных участников, что подтверждается ростом инвестиционной привлекательности сети: в 2025 году к числу акционеров присоединились Abu Dhabi Uzbek Investment и Uzbek-Oman Investment Company [7; 8].

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У компании Samsung внедрение цифровых инструментов персонализации, включая AI-платформу электронной коммерции Shop Samsung, сопровождается ростом среднего чека на 35% [9]. Использование AI-ассистента Bixby, обрабатывающего свыше 38 млн запросов ежемесячно и разрешающего 92% обращений без участия сотрудников, способствует снижению операционных затрат на обслуживание клиентов [9]. При этом 68% пользователей сохраняют приверженность бренду Samsung на протяжении более пяти лет, что отражает долгосрочный эффект персонализированного взаимодействия с клиентами на удержание аудитории [9].

Представленные данные свидетельствуют о том, что внедрение CRM-систем положительно влияет на ключевые показатели деятельности предприятий. Несмотря на различия в масштабе бизнеса и отраслевой специфике, опыт Samsung и Korzinka подтверждает, что использование CRM способствует росту продаж, повышению лояльности клиентов, развитию цифровых каналов взаимодействия и укреплению конкурентных преимуществ компаний.

Обсуждение результатов

Полученные результаты показывают, что экономический эффект CRM проявляется по-разному в зависимости от масштаба и профиля компании. У сети Korzinka основной эффект сосредоточен в сфере развития цифровых каналов продаж: опережающий рост выручки онлайн-сервиса Korzinka Go (188%) относительно роста сопоставимых продаж офлайн-магазинов (9,3%) отражает структурный сдвиг потребительского поведения в сторону цифровых форматов покупок, поддерживаемый программой лояльности с 1,8 млн активных участников. Для инвесторов этот результат стал одним из факторов, способствовавших привлечению капитала международных фондов в 2025 году.

У компании Samsung, напротив, эффект CRM проявляется преимущественно через удержание клиентов и снижение операционных издержек: показатель удержания на уровне 68% на протяжении пяти и более лет и высокая доля автоматически разрешаемых обращений (92%) свидетельствуют о зрелой модели персонализированного взаимодействия, в которой цифровые инструменты снижают стоимость обслуживания при сохранении лояльности крупной клиентской базы. Рост среднего чека на 35% при этом связан не с привлечением новых клиентов, а с более точным таргетированием предложений внутри существующей базы.

Сопоставление двух кейсов позволяет оценить соответствие исследовательской гипотезе, сформулированной во введении. Гипотеза о том, что экономическая эффективность

CRM определяется не только ростом продаж, но и комплексным влиянием на удержание клиентов, издержки и цифровые каналы, подтверждается данными обеих компаний, хотя структура эффекта различается: у Korzinka преобладает эффект роста цифровых каналов продаж, у Samsung — эффект удержания и снижения издержек. Это подчёркивает, что оценка эффективности CRM только через показатель роста выручки является упрощённой и должна дополняться показателями удержания, стоимости обслуживания и структуры каналов продаж, что соответствует системе индикаторов, представленной в таблице 1.

Настоящее сопоставление имеет ограничения: данные по компаниям получены из открытых отчётов и аналитических материалов, которые могут не раскрывать полную методологию расчёта отдельных показателей (в частности, детали расчёта роста среднего чека и удержания клиентов Samsung), что снижает сопоставимость с внутренними финансовыми показателями Korzinka, публикуемыми в официальном годовом отчёте.

Заключение

Исследовательская гипотеза о том, что экономическая эффективность внедрения CRM-систем определяется не только ростом объёма продаж, но и комплексным влиянием на удержание клиентов, операционные издержки и развитие цифровых каналов продаж, получила подтверждение. Мировой рынок CRM-систем демонстрирует устойчивый рост — до 163,16 млрд долл. США к 2030 году при среднегодовом темпе роста 14,6%, оставаясь крупнейшим сегментом рынка корпоративного программного обеспечения. Кейс-анализ показал, что у сети Korzinka экономический эффект CRM выражается прежде всего в опережающем росте цифровых каналов продаж (Korzinka Go: +188%) и расширении базы лояльности (1,8 млн активных участников), тогда как у компании Samsung — в удержании клиентов (68% на протяжении пяти и более лет) и снижении издержек на обслуживание за счёт автоматизации (92% обращений через Bixby).

Научная новизна работы состоит в сопоставлении экономического эффекта CRM-систем у компаний принципиально разного масштаба — многонациональной корпорации и национальной розничной сети — в условиях цифровой трансформации экономики Узбекистана, что позволяет показать различие в структуре экономического эффекта CRM в зависимости от масштаба и профиля деятельности компании. Практическая значимость результатов состоит в возможности использования представленной системы показателей (ROI, CAC, CLV, Customer Retention Rate, Conversion Rate)

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отечественными предприятиями при выборе и оценке эффективности CRM-решений, а также при обосновании инвестиций в цифровую трансформацию клиентских сервисов.

Настоящее исследование имеет ряд ограничений. Во-первых, анализ основан на данных, опубликованных в открытых источниках и годовых отчётах компаний, без доступа к внутренней управленческой отчётности и детальной методологии расчёта отдельных показателей. Во-вторых, кейс-анализ ограничен двумя компаниями и не может быть непосредственно распространён на предприятия

иных отраслей без дополнительного сравнительного исследования. В-третьих, представленные показатели отражают преимущественно операционные и клиентские эффекты CRM и не включают полную оценку затрат на внедрение и сопровождение систем.

Перспективным направлением дальнейших исследований является расширение выборки кейс-анализа на предприятия иных отраслей, включая топливно-энергетический сектор Узбекистана, а также изучение применения технологий искусственного интеллекта и предиктивной аналитики в развитии современных CRM-систем.

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Article



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UNDERSTANDING STUDENTS' NUMERACY COMPETENCE THROUGH THE LENS OF CONFIDENCE IN PROBLEM SOLVING AND ATTITUDE TOWARDS MATHEMATICS

Abstract: This study assessed the relationship between attitudes towards mathematics, problem-solving confidence, and numeracy skills of Grade 9 students. A total of 100 respondents were surveyed using standardized questionnaires and numeracy assessments. The study examined demographic profiles, parental educational attainment, and household income as contextual variables. Results revealed that the majority of respondents come from families with college-level education and middle-income households. In terms of attitudes towards mathematics, students exhibited a neutral overall disposition, with high recognition of the value of mathematics, moderate self-confidence, enjoyment, and motivation. Problem-solving confidence was generally moderate, with students showing persistence in challenging tasks but experiencing occasional stress and fear of errors. Numeracy skills varied, with most students classified at the basic level, indicating foundational competence but limited proficiency in complex mathematical operations. Spearman's rho correlation analyses indicated a negligible positive relationship between attitudes towards mathematics and numeracy skills, which was not statistically significant. In contrast, problem-solving confidence showed a statistically significant, albeit weak, positive correlation with numeracy performance. These findings suggest that fostering problem-solving confidence may have a greater impact on enhancing students' numeracy skills than attitudes alone. The study highlights the importance of supportive instructional strategies, scaffolded problem-solving activities, and differentiated learning to strengthen numeracy competence and confidence. Interventions aimed at improving both cognitive skills and affective dispositions toward mathematics are recommended to promote overall mathematical competence and engagement.

Key words: Teaching Mathematics, attitudes towards mathematics, problem-solving confidence, numeracy skills, Grade 9 students, mathematical competence, descriptive-correlational design, Minglanilla, Cebu.

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Introduction

Chapter 1

THE PROBLEM AND ITS SCOPE

INTRODUCTION

Rationale of the Study

The development of numeracy competence, confidence in problem solving, and a positive attitude towards mathematics has become a central focus in improving mathematics education globally, as these interrelated factors shape learners' ability to understand concepts, think critically, and apply mathematical skills to real-life situations. International research emphasizes that numeracy extends beyond basic computation; it involves interpreting information, making logical decisions, and solving everyday problems (Hodge et al., 2021). Likewise, confidence in problem solving has been consistently linked to students' perseverance, strategic thinking, and overall performance in mathematics (Zakariya et al., 2022). Meanwhile, students' attitude toward mathematics—whether positive or negative—plays a crucial role in shaping their motivation, engagement, and long-term success in the subject.

In the Philippine context, concerns about numeracy skills and learners' disposition toward mathematics continue to arise. National and international assessments show that Filipino students often struggle with mathematical reasoning, higher-order thinking skills, and real-life problem-solving tasks (Mangilala et al., 2021). The 2022 Programme for International Student Assessment (PISA) reported that the Philippines remains below the international average in mathematical literacy, with many learners demonstrating difficulties in applying mathematics to everyday scenarios (OECD, 2023). Similarly, the National Achievement Test (NAT) results reveal a persistent pattern of low performance in secondary-level mathematics, particularly in items requiring multi-step analysis and logical interpretation (Casildo, 2023).

These national trends are likewise reflected in many public schools across the country, including schools within the local community, where teachers observe that students struggle not only with basic numeracy tasks but also with sustaining confidence when faced with non-routine or unfamiliar problems. Many learners experience anxiety, lack of motivation, and negative attitudes toward mathematics, which further hinder their performance. Despite the Department of Education's ongoing initiatives such as the Rapid Mathematics Assessment (RMA) and

numeracy strengthening programs—gaps in foundational skills remain visible, especially among Grade 9 learners who are expected to transition from basic arithmetic to more abstract mathematical concepts.

Grade 9 is a particularly challenging year, as the curriculum introduces topics that require both computational fluency and conceptual understanding. Students with weak numeracy foundations often rely on memorization rather than comprehension, leading to errors and loss of confidence when solving problems. Research also shows that negative attitudes such as fear of failure, low interest, or the belief that mathematics is inherently difficult—can diminish students' willingness to attempt challenging tasks, further widening performance gaps (Lara et al., 2025). In the context of a private secondary school in Minglanilla, Cebu, mathematics teachers have observed that a number of Grade 9 learners struggle to apply basic numerical concepts in problem-solving tasks despite having access to adequate learning resources and instructional support. Classroom observations and informal assessments reveal that some students exhibit hesitation when answering mathematical problems, avoid participation during problem-solving activities, and express low confidence in their mathematical abilities. These challenges are often accompanied by negative attitudes toward mathematics, such as anxiety during assessments and a tendency to perceive mathematics as a difficult and intimidating subject.

These local observations highlight the need to examine not only learners' numeracy competence but also their confidence in problem solving and overall attitude toward mathematics. Given these pressing concerns, it becomes essential to understand how these three dimensions interact within the context of local Grade 9 learners. By exploring these relationships, teachers and curriculum planners can better identify the specific barriers that hinder students' learning and develop targeted interventions to strengthen both skill and disposition.

Thus, this study, "Understanding Students' Numeracy Competence Through the Lens of Confidence in Problem Solving and Attitude Towards Mathematics," seeks to provide a localized and evidence-based understanding of the factors affecting learners' mathematical performance. The findings of this research will serve as a basis for designing an Enhancement Plan, which aims to support Grade 9 learners in cultivating positive mathematical mindsets, and improving overall learning outcomes in mathematics.

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Theoretical Background

This study is anchored on the following theories: Albert Bandura’s Social Cognitive Theory (1986) and Self-Efficacy Theory (1977), Jean Piaget’s Cognitive Development Theory (1970), Carol Dweck’s Growth Mindset Theory (2006), John Flavell’s Metacognitive Theory (1979), and John Sweller’s Cognitive Load Theory (1988).

This research is also legally anchored on

Republic Act No. 10533, also known as “The Enhanced Basic Education Act of 2013”; DepEd Order No. 8, s. 2015, otherwise known as “Policy Guidelines on Classroom Assessment for the K-12 Basic Education Program; DepEd Order No. 21, s. 2019, also known as “Policy Guidelines on the K - 12 Basic Education Program; and Republic Act No. 9155, also known as Governance of Basic Education Act of 2001.

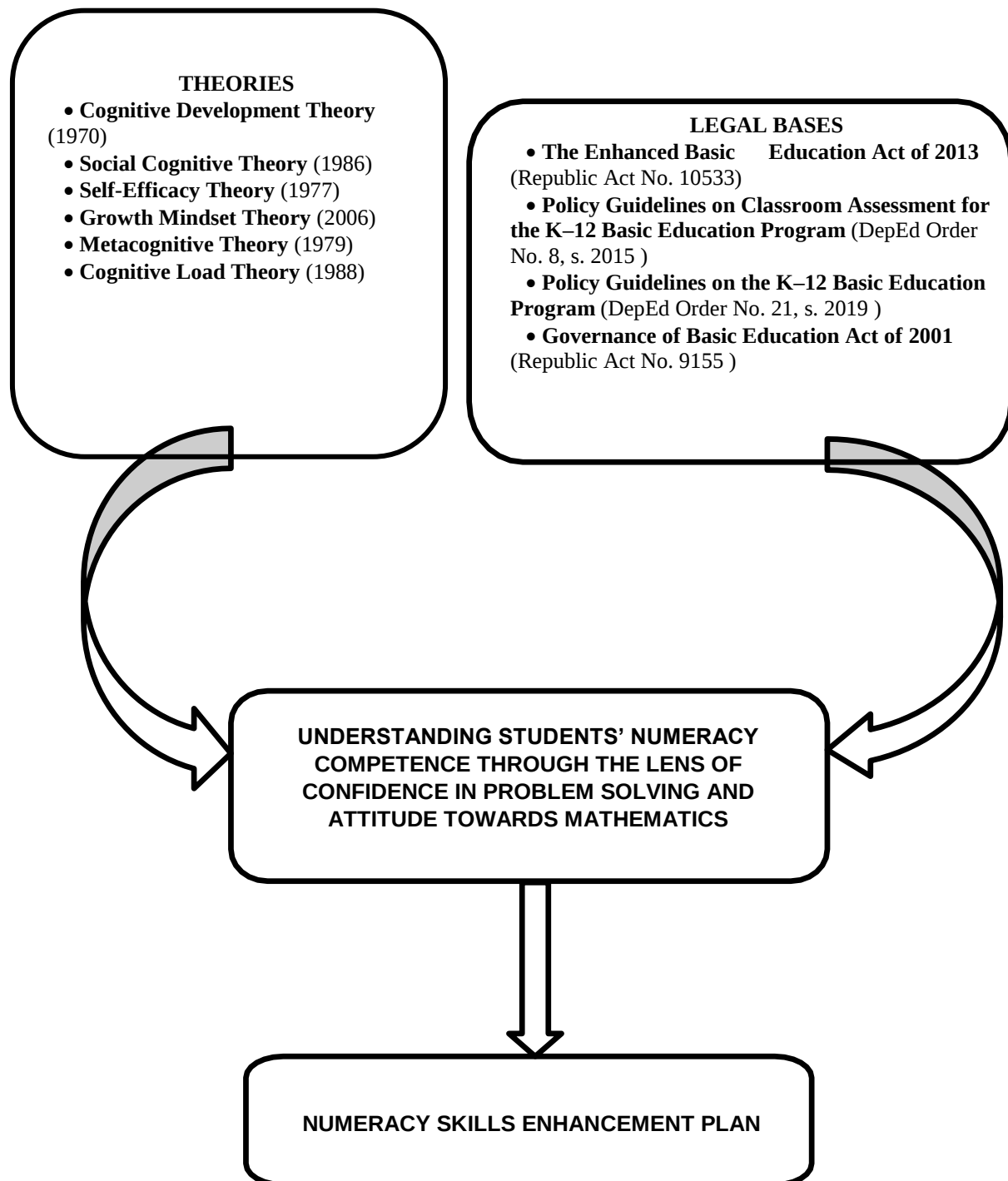


Figure 1: Theoretical-Conceptual Framework of the Study

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Albert Bandura's Social Cognitive Theory (1986) posits that learning occurs through reciprocal interactions among personal factors, behavior, and environment, a process referred to as reciprocal determinism. This theory is particularly relevant in understanding how students develop numeracy competence, problem-solving confidence, and attitude toward mathematics because learning is shaped not only by individual ability but also by social context. In the mathematics classroom, students gain confidence and form attitudes by observing teachers demonstrate problem-solving strategies, seeing classmates engage successfully in tasks, and receiving constructive feedback from peers and adults. Positive social modeling fosters engagement, enhances confidence in problem solving, and cultivates a positive attitude toward mathematics, while negative social experiences or lack of guidance can increase anxiety and reduce both confidence and numeracy performance. Thus, Social Cognitive Theory provides a framework for understanding how classroom interactions and social influences shape students' mathematical competence as well as their affective responses to learning.

Bandura's Self-Efficacy Theory (1977) further emphasizes that students' beliefs about their capabilities strongly determine their motivation, persistence, and achievement in mathematics. Learners with high self-efficacy approach numeracy tasks with determination, maintain confidence when facing challenging problems, and are more likely to develop positive attitudes toward mathematics. Conversely, students with low self-efficacy are more prone to avoidance behaviors, negative attitudes, and decreased engagement, which can hinder the development of numeracy skills. Therefore, problem-solving confidence and attitude toward mathematics can be viewed as psychological mediators that directly influence the acquisition of numeracy competence, illustrating how self-perception drives both cognitive and affective aspects of learning.

Jean Piaget's Cognitive Development Theory (1970) explains that Grade 9 learners typically transition into the formal operational stage, a period characterized by the emergence of abstract reasoning, logical thinking, and systematic problem solving. Numeracy competence, particularly in algebra, geometry, and statistical reasoning, relies heavily on these cognitive abilities. When mathematical tasks match students' developmental readiness, learners experience mastery, which strengthens their problem-solving confidence and promotes positive attitudes toward mathematics. In addition, tasks that exceed cognitive capacity may lead to confusion, frustration, and negative attitudes, which can impede both confidence and the development of numeracy skills. Piaget's theory thus provides a developmental lens for understanding how the interplay of cognitive readiness, problem-solving confidence, and attitude

contributes to successful mathematics learning.

Carol Dweck's Growth Mindset Theory (2006) offers insight into students' beliefs about their ability to develop mathematical skills. Learners with a growth mindset, who believe that effort and persistence can improve mathematical ability, are more likely to embrace challenges, sustain confidence in problem solving, and maintain positive attitudes toward mathematics. In contrast, learners with a fixed mindset may avoid difficult tasks, experience diminished confidence, and develop negative attitudes, which can hinder numeracy development. Growth mindset therefore provides a psychological foundation for improving both problem-solving confidence and attitudes, which in turn support the development of numeracy competence.

John Flavell's Metacognitive Theory (1979) emphasizes learners' ability to monitor, regulate, and evaluate their cognitive processes. In mathematics, metacognitive skills such as planning solutions, monitoring progress, and checking for errors enable students to approach problems systematically, increasing problem-solving confidence. Learners who are metacognitively aware are also more likely to develop positive attitudes toward mathematics, as they feel more in control of their learning and less frustrated when encountering difficulties. Hence, metacognitive competence strengthens both confidence and attitudes, which enhances numeracy performance and fosters deeper understanding of mathematical concepts.

John Sweller's Cognitive Load Theory (1988) highlights the limitations of working memory in processing complex information. When mathematics tasks impose excessive cognitive load, learners may experience confusion, frustration, and decreased confidence, which negatively affect both attitudes and numeracy competence. On the other hand, instruction that is scaffolded and appropriately sequenced reduces cognitive load, allowing students to acquire problem-solving skills, build confidence, and develop more positive attitudes toward mathematics. Cognitive Load Theory thus demonstrates how instructional design influences the simultaneous development of competence, confidence, and affective dispositions in mathematics learning.

The theoretical foundations of this study are further supported by Philippine educational policies that emphasize the integrated development of knowledge, skills, and attitudes:

The Enhanced Basic Education Act of 2013 (Republic Act No. 10533). This act institutionalized the K–12 program, extending basic education to strengthen foundational competencies in literacy and numeracy (Violon & Violon, 2024). It mandates the integration of critical thinking, problem-solving, and lifelong learning skills as core competencies across grade levels. The law serves as a cornerstone for ensuring that learners acquire essential mathematical

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proficiency before advancing to higher education or the workforce.

Policy Guidelines on Classroom Assessment for the K–12 Basic Education Program (DepEd Order No. 8, s. 2015). This policy emphasizes the importance of formative and summative assessments to measure learners' numeracy performance and analytical reasoning (Sabado, 2021). It aligns with diagnostic tools such as the Rapid Mathematics Assessment (RMA), which helps identify numeracy gaps and guides appropriate instructional interventions.

Policy Guidelines on the K–12 Basic Education Program (DepEd Order No. 21, s. 2019). This order highlights the integration of problem-solving, reasoning, and communication skills in mathematics instruction (Cerezo et al., 2023). It calls for contextualized and learner-centered approaches that promote both skill mastery and confidence.

Together, these legal bases ensure that mathematics instruction in the Philippines not only builds computational competence but also fosters self-efficacy and resilience in problem solving.

Governance of Basic Education Act of 2001 (Republic Act No. 9155). This act emphasizes school-level accountability in creating supportive learning environments. It mandates that learning experiences should cultivate essential competencies, including numeracy, and foster critical thinking, confidence, and positive attitudes toward academic subjects such as mathematics (Uy & Ocampo, 2023).

Recent empirical studies have consistently established a positive association between numeracy skills and problem-solving confidence or self-efficacy. Numeracy, or mathematical literacy, as defined in foundational frameworks such as OECD's PISA 2022 Mathematics Framework, encompasses applied reasoning, modelling, and evaluation tasks, which are closely linked to students' confidence in solving realistic problems (OECD, 2022). This is complemented by a systematic review of intervention studies (project-based learning, mastery learning, feedback-oriented instruction) conducted by Zakariya (2022) and found consistent gains in Mathematics self-efficacy when learning designs targeted both skill and reflective affective components. Experimental study conducted by Nurhasanah et al. (2024) showed that project-based learning (PjBL) significantly improved both numeracy test scores and Mathematics self-efficacy. Similarly, the Concrete-Pictorial-Abstract (CPA) approach has been shown in several quasi-experimental studies to elevate numeracy outcomes alongside increased confidence, especially in early secondary school cohorts (Iyamuremye et al., 2025; Rozata et al., 2024). Likewise, studies on using digital tools and dynamic visualization further support this relationship. Zhang et al. (2023) and Barçın et al. (2023) reported that students exposed to dynamic visualization tools such

as GeoGebra performed better on problem-solving tasks and exhibited higher self-efficacy than those engaged in static visual instruction.

Moderation effects have also emerged in international research, demonstrating that the link between self-efficacy and performance is influenced by contextual variables. Shimizu (2022) found that learning engagement moderates the relationship between self-efficacy, Math anxiety, and problem-solving performance, indicating that the predictive effect of self-efficacy strengthens when students are highly engaged. Kaskens et al. (2020) observed that teacher competency and classroom environment enhance the predictive power of children's self-efficacy and self-concept for numeracy development. Cross-country analyses used PISA 2022 data revealed that creative learning environments, combined with high self-efficacy correlate with stronger applied numeracy performance (Wang, Perry & Ide, 2023).

In the Philippines, empirical evidence similarly points to a positive association between numeracy and problem-solving confidence, although variations have been observed in measurement approaches, contextual factors, and effect sizes. Rodil (2024) documented that students' self-reported confidence often exceeds their actual problem-solving performance, suggesting that self-report measures should be complemented with objective assessments. Norcio and Villahermosa (2021) addressed this by developing a numeracy assessment tool centered on Grade 9 learners' understanding of quadratic equations, allowing objective skills to be compared with confidence ratings. Project COUNTS (Munda et al., 2024) and Project NUMEROS (Aguilar et al., 2025) are two program evaluation studies in junior high school that revealed significant pre- and post-test gains in numeracy performance but also noted that improvements in confidence and self-efficacy occur mostly when there is teacher guidance, coaching and contextualized tasks.

At the methodological level, Echavez et al. (2024) conducted a systematic review of literacy and numeracy studies in the Philippines and identified several recurring limitations, including small sample sizes, non-standardized instruments for measuring confidence, and inconsistent reporting of reliability and effect sizes. Across both international and Philippine research, several instructional approaches have been consistently associated with improved numeracy performance and higher confidence levels. Strategies such as Realistic Mathematics Education (RME), the Concrete–Pictorial–Abstract (CPA) approach, project-based learning, contextualized tasks, and the integration of digital visualization tools have demonstrated effectiveness when properly implemented. Methodologically, the more rigorous studies utilize quasi-experimental or true-experimental designs with pretest–posttest measures, employ validated instruments for assessing numeracy

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and self-efficacy, and apply robust statistical analyses such as Pearson correlation, regression models, and moderation analyses. For instance, studies by Nurhasanah (2024) and Shimizu (2022) report measurable effect sizes and incorporate engagement and classroom factors as moderating variables.

Across the reviewed literature, numeracy and problem-solving confidence emerge as closely interrelated constructs. However, few studies in the Philippine context have directly examined this relationship, particularly among Grade 9 students, a critical stage marking the shift from concrete arithmetic to abstract mathematical reasoning. Most available studies focus on interventions or complex modeling rather than direct correlational analysis. This study addresses the gap by exploring the relationship between numeracy skills and problem-solving confidence among Grade 9 learners, providing insights into how cognitive and affective factors interact to shape mathematical learning during this key developmental stage.

THE PROBLEM

Statement of the Problem

This study assessed the attitudes towards Mathematics, problem-solving confidence, and numeracy skills of Grade 9 students at a secondary private school in Cebu Province for School Year 2025–2026 as a basis for Numeracy Skills Enhancement Plan.

Specifically, this study sought to answer the following questions:

1. What is the profile of the respondents in terms of:
 - 1.1 age and gender;
 - 1.2 parents' highest educational attainment; and
 - 1.3 combined family monthly income?
2. What is the level of the attitudes of the respondents towards Mathematics in terms of:
 - 2.1 Self-confidence;
 - 2.2 Value of Mathematics;
 - 2.3 Enjoyment in Mathematics; and
 - 2.4 Motivation in Mathematics?
3. What is the level of problem-solving confidence of the respondents?
4. What is the level of numeracy skills of the respondents?
5. Is there a significant relationship between the:
 - 5.1 respondents' attitudes towards Mathematics and their numeracy skills; and
 - 5.2 respondents' problem-solving confidence and their numeracy skills?
6. Based on the findings, what Numeracy Skills Enhancement Plan can be proposed?

Statement of the Null Hypotheses

Based on the objectives of the study, the following null hypothesis were tested at 0.05 level of significance:

Ho₁: There is no significant relationship between the respondents' attitudes towards Mathematics and their numeracy skills.

Ho₂: There is no significant relationship between the respondents' problem-solving confidence and their numeracy skills.

Significance of the Study

The present study, which examines the relationship between numeracy skills and problem-solving confidence among Grade 9 students holds considerable significance for several key stakeholders:

Department of Education. For policymakers and officials in the Department of Education, this research provides empirical evidence that may guide curriculum review and policy development in mathematics education. It highlights the importance of integrating both cognitive (numeracy) and affective (confidence) domains in mathematics learning, supporting the development of programs that enhance student performance and self-efficacy.

School Administrators. The results of this study can help school administrators design and implement intervention programs that strengthen both numeracy skills and confidence in problem-solving. Insights from this research may also inform school-based initiatives to address gaps in mathematics achievement and encourage a positive learning environment.

Teachers. Mathematics teachers can benefit from the study by gaining a deeper understanding of how numeracy and confidence interact in the classroom. The findings can help them choose more effective instructional strategies that not only improve mathematical proficiency but also build problem-solving confidence.

Learners. The results of the study are beneficial to the students themselves, as it emphasizes the value of developing both strong numeracy skills and confidence in problem-solving. With increased awareness of these factors, learners may be motivated to engage more actively in mathematics, ultimately improving their academic performance and self-belief.

Parents. Parents can use the findings to better understand how their children's numeracy skills and confidence levels interact. This knowledge can encourage more effective parental support at home, whether through helping with problem-solving tasks or fostering a positive attitude towards mathematics learning.

School Community. The study supports the entire school community in promoting a culture that values both competence and confidence in mathematics. By recognizing the dual importance of

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skills and attitudes, schools can cultivate a more holistic and supportive environment for learners.

Researcher. For the researcher, this study contributes to professional growth and expertise in the field of mathematics education. It provides firsthand experience in conducting empirical research and offers insights that may guide future academic and professional pursuits..

Future Researchers. This study serves as a useful reference for future studies exploring the interplay of numeracy skills, confidence, and other affective factors in mathematics education. It can also be replicated or extended to other grade levels or contexts, contributing to the growing body of literature on mathematics learning and self-efficacy.

RESEARCH METHODOLOGY

This section presented the research design, respondents, research environment, instruments used, data-gathering procedure, ethical considerations, scoring procedure, and statistical tools employed in the study.

Design

The present study utilized a descriptive–correlational research design. This design is appropriate for research that seeks to describe variables as they naturally occur within a population and to examine the degree of association between or among them without exerting experimental manipulation (Seeram, 2019).

Because the variables under investigation already exist and were not subjected to treatment or intervention, a correlational approach was deemed most suitable. This design allowed the researcher to obtain quantitative measures of attitudes, confidence, and numeracy competence through the use of standardized and adopted research instruments, and to statistically analyze their interrelationships. The results derived from this design further served as the empirical basis for formulating the proposed Numeracy Skills Enhancement Plan.

Flow of the Study

The study followed an Input–Process–Output (IPO) framework to organize the variables, research activities, and expected outcome of the investigation. This model provides a systematic representation of how the study was carried out in relation to the research problems and intended output. Figure 2 illustrates the process of data gathering.

This phase included the identification of the respondents’ profiles (age, gender, parents’ highest educational attainment, and combined monthly income), their attitudes toward Mathematics in terms of self-confidence, value of Mathematics, enjoyment, and motivation, their level of problem-solving confidence, and their numeracy skills as assessed through the adapted numeracy test. The input also included the determination of the significant relationships between (a) attitudes toward Mathematics and numeracy skills, and (b) problem-solving confidence and (c) numeracy skills.

The process phase involved the major research activities undertaken in the study, such as the selection of respondents through purposive sampling, administration of the adopted research instruments, and the organization, tabulation, and statistical treatment of the gathered data. Appropriate statistical tools—including frequency, percentage, mean, standard deviation, and Pearson r correlation—were applied to analyze and interpret the findings in alignment with the research objectives.

Based on the results of the data analysis, the researcher developed a Numeracy Skills Enhancement Plan. This enhancement plan aims to improve learners’ numeracy skills and strengthen their problem-solving confidence through regular diagnostic assessments, guided feedback, and targeted learning activities. The plan serves as the practical output of the study and is intended to address identified gaps in numeracy performance and confidence among Grade 9 students.

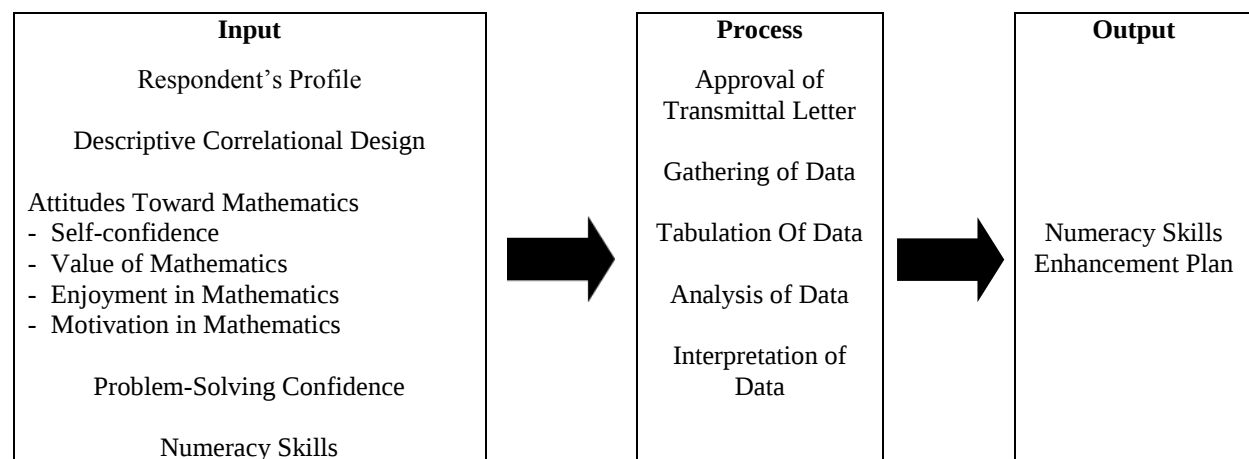


Figure 2. Flow of the Study

Impact Factor:

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ICV (Poland) = 6.630
 PIF (India) = 1.940
 IBI (India) = 4.260
 OAJI (USA) = 0.350

Environment

The study was conducted at a private school in Minglanilla, Cebu. This school implement the Department of Education's K-12 Basic Education

Curriculum and offer Grade 9 Mathematics, making this a suitable site for assessing numeracy skills, attitudes toward Mathematics, and problem-solving confidence.



Figure 3. Location Map of the Research Environment

The institution maintains classrooms equipped with essential learning resources and instructional materials that facilitate the delivery of mathematics

lessons, including numeracy-focused activities, problem-solving tasks, and performance-based assessments. Teachers regularly implement varied

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teaching strategies to cater to different learner needs, making the school a suitable setting for examining students' numeracy competence, problem-solving confidence, and attitudes toward mathematics.

The presence of supportive school administrators, trained mathematics teachers, and established academic programs contributes to an environment conducive to data collection. The school's commitment to continuous improvement and learner development ensures that the findings of this study are relevant for enhancing mathematics instruction and supporting evidence-based educational practices.

Respondents

The respondents of this study were Grade 9 learners enrolled during School Year 2025–2026. They were selected through purposive sampling, a method appropriate for identifying individuals who meet specific criteria relevant to the study; namely, students currently exposed to mathematics lessons that develop numeracy skills, attitudes toward Mathematics, and problem-solving confidence. This sampling technique ensured that the data collected would be meaningful and directly aligned with the objectives of the study. The sample distribution of the respondents is presented in Table 1 below.

Table 1 - Distribution of the Respondents

Grade 9	n	%
Section 1	49	49.00
Section 2	51	51.00
Total	100	100.00

The respondents of this study were 100 Grade 9 students enrolled at St. Cecilia's College – Cebu, Inc. during the academic year. They were selected to participate because Grade 9 is a critical stage in the development of numeracy competence, particularly in algebraic reasoning, problem-solving, and higher-order mathematical skills.

As shown in the table, the respondents were distributed across two Grade 9 sections. Section 1 consisted of 49 students (49%), while Section 2 had 51 students (51%). This nearly equal distribution ensures balanced representation across the grade level, supporting fair and reliable analysis of students' numeracy skills, problem-solving confidence, and attitudes toward mathematics.

Instrument

The researcher utilized adopted research instruments to obtain the data necessary for the study. These instruments measured the respondents' profile, attitudes toward Mathematics, problem-solving confidence, and numeracy skills. The instruments used were as follows:

Part I. Profile of the Respondents. This section was designed to gather demographic information from the respondents. The profile included: name(optional), age, gender, parents' highest educational attainment, and combined monthly income.

Part II. Students' Attitude Toward Mathematics. This scale measured the attitudes of Grade 9 learners toward Mathematics across four domains: self-confidence in Mathematics, value of Mathematics, enjoyment in Mathematics, and

motivation in Mathematics. It was adopted from the Attitude towards Mathematics Inventory questionnaire by Tapia and Marsh (2004). The instrument consisted of positively and negatively worded items rated on a 5-point Likert scale (1–Strongly Disagree to 5–Strongly Agree). Higher mean scores reflected more positive attitudes toward Mathematics.

Part III. The Problem-Solving Confidence of the Learners. This part measured the confidence level of Grade 9 students in solving mathematics problems. It was adopted from the Problem-Solving Confidence Questionnaire developed by Gok (2012). The instrument consisted of 20 worded statements reflecting students' confidence in problem solving, rated on a 5-point Likert scale: (1–Strongly Disagree to 5–Strongly Agree). Higher scores indicated higher problem-solving confidence in numeracy.

Part IV. The Numeracy Test. This part assessed the numeracy skills of the Grade 9 students. The 40-item numeracy test adopted from Department of Education's Rapid Mathematics Assessment (RMA), which covered essential mathematical concepts and problem-solving skills aligned with the Grade 9 mathematics curriculum. The items included operations involving polynomials, solving linear and quadratic equations using various methods (factoring, completing the square, and the quadratic formula), and problems on direct variation. The test was designed to measure students' understanding, computation, and application skills in mathematics. Each correct answer was given one point, and the total score represented the student's numeracy level. Higher scores indicated higher numeracy proficiency.

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Data Gathering Procedures

Preparatory Stage. The researcher sent a letter to the office of the school's division superintendent at the Department of Education, Cebu Province Division. After it was approved, the researcher carried the letter by hand and gave it to the school principal of the school to formally inform the researcher's intention and to schedule a meeting with the teacher and student respondents for the conduct of the survey.

Data Gathering Stage. On the scheduled day of data collection, the researcher conducted an orientation session last November 26, 2025 to explain the purpose of the study, the procedures involved, and the rights and protections of the participants. Ethical considerations—including voluntary participation, the right to withdraw at any time, and assurances of confidentiality—were clearly emphasized. The respondents were informed that their personal information and responses would be handled in compliance with data privacy standards and used solely for academic purposes.

After the orientation, the survey questionnaires were administered on the same day. Clear instructions were provided on how to accomplish each part of the instrument. The researcher remained available to clarify questions while ensuring that responses were completed independently. Sufficient time was allotted for answering, and all completed questionnaires were retrieved immediately after the session to maintain data integrity and confidentiality.

Post Data Gathering Stage. When the scores were carefully gathered, it was individually encoded and tabulated using Excel. The variables which were found in the statement of the problem were extracted, using a summary sheet that contains all the required information from this study. Then, the data were statistically treated, analyzed, and tabulated orderly. Furthermore, the interpretations were made possible based on the outcomes from the statistical tools used. Likewise, the data from the outcome was discussed in parallel according to the arrangement presented in the statement of the problem. To validate the data more, additional related studies were provided to elaborate the discussion.

Statistical Treatment of Data

After data collection, the data gathered had undergone different statistical treatments with the aid of the statistician. To arrive at reliable results, the following statistical tools were used:

Frequency. This tool was used to determine the number of characteristics in which the respondents fell in the same category, particularly in the profile. Each response was recorded and tallied.

Simple Percentage. This tool was utilized to describe the proportion of the respondents who belong to the same category as the total number of respondents specifically on their profile.

Weighted Mean. The mean was used to determine the respondents' overall level of attitudes toward Mathematics, their problem-solving confidence, and their numeracy skills.

Standard Deviation. This measure was used to determine the variability or dispersion of the respondents' scores from the mean in the attitude scale, problem-solving confidence scale, and numeracy test.

Spearman Rho (rho). This statistical tool was used to determine the significance of the relationship between attitudes toward Mathematics and numeracy skills, and problem-solving confidence and numeracy skills.

Scoring Procedure

Data that were collected through the research instruments were calculated and interpreted according to the following procedures:

To determine the respondents' attitude towards Mathematics, the responses from the Likert-scale questionnaire adopted from Tapia and Marsh (2004) were tallied and interpreted using the scale below. Each item was rated on a five-point Likert scale, with responses ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The weighted mean and standard deviation were computed per item, per domain (self-confidence, value of math, enjoyment of math, and motivation), and as a composite score. These were interpreted using the following scale:

Table 2

Scale	Numerical rating	Descriptive Rating	Description
5	4.21 — 5.00	Very Positive	The student consistently demonstrates a very positive attitude toward Mathematics, showing strong interest, enjoyment, and confidence in engaging with mathematical tasks.

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4	3.41 – 4.20	Positive	The student generally shows a positive attitude toward Mathematics, with interest and willingness to learn, though occasional doubts or hesitations may arise.
3	2.61 – 3.40	Neutral	The student sometimes feels comfortable with Mathematics but may show mixed feelings, experiencing both interest and uncertainty depending on the task.
2	1.81 – 2.60	Negative	The student often displays a negative attitude toward Mathematics, frequently feeling hesitant, discouraged, or unsure when working with mathematical concepts.
1	1.00 – 1.80	Very Negative	The student rarely demonstrates a positive disposition toward Mathematics and often shows avoidance, discomfort, or strong doubts about their mathematical abilities.

To determine the respondents' level of problem-solving confidence, the responses from the Likert-scale questionnaire adopted from Gok (2012) were tallied, scored, and interpreted using the scale below.

Each item was rated on a five-point Likert scale, with responses ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

Table 3

Scale	Numerical rating	Descriptive Rating	Description
5	4.21 – 5.00	Very High Confidence	The student consistently demonstrates very high confidence in solving mathematics problems and believes strongly in their ability to succeed in numeracy tasks.
4	3.41 – 4.20	High Confidence	The student generally shows high confidence in solving mathematics problems, with only minor doubts or hesitations.
3	2.61 – 3.40	Moderate Confidence	The student sometimes feels confident in solving mathematics problems but may experience occasional self-doubt or uncertainty.
2	1.81 – 2.60	Low Confidence	The student often lacks confidence when faced with mathematics problems and may be hesitant in applying problem-solving strategies.
1	1.00 – 1.80	Very Low Confidence	The student rarely demonstrates confidence in solving mathematics problems and often doubts their ability in numeracy.

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To determine the respondents' level of numeracy skills, the 40-item numeracy test was scored by assigning one point for each correct answer and zero for each incorrect answer. The

total score was computed for every learner, and the results were interpreted using the numeracy mastery-level scale presented below.

Table 4

Score Range	Numeracy Level	Description
33–40	Advanced	Demonstrates excellent numeracy and reasoning ability.
25–32	Proficient	Strong understanding and problem-solving skills.
17–24	Basic	Understands fundamental concepts; minor errors in complex problems.
9–16	Developing	Limited skills; needs guided practice.
0–8	Beginning	Struggles with basic numeracy skills; needs remediation.

To determine the relationship between the variables, the study employed the Spearman Rho (rho). This statistical tool was used to examine the relationship between:

- (1) the respondents' attitudes toward Mathematics and their numeracy skills, and
- (2) their problem-solving confidence and numeracy skills.

Ethical Considerations

This study was conducted in accordance with accepted ethical standards in educational research to ensure the protection, dignity, and welfare of all participants. Prior to data collection, permission to conduct the study was secured from the school administration. Participation of the respondents was voluntary, and informed consent was obtained, emphasizing that participants had the right to withdraw from the study at any stage without any penalty.

Confidentiality and anonymity of the respondents were strictly maintained. No names or personally identifiable information were recorded in the research instruments. Codes were used in place of identities to ensure that individual responses could not be traced back to specific participants.

In compliance with the Data Privacy Act of 2012 (Republic Act No. 10173), all data gathered were used solely for academic and research purposes. Collected data were securely stored and accessed only by the researcher. Electronic files were password-protected, while printed materials were kept in a secured location. After the completion of the study, all data will be properly disposed of

following ethical research guidelines.

Overall, the study ensured that ethical principles of respect, beneficence, and integrity were upheld throughout the research process.

DEFINITION OF TERMS

The following terms are operationally defined according to how it is used in the study for better understanding:

Attitude Toward Mathematics (ATM). Refer to a learner's overall disposition, feelings, and beliefs about mathematics, including their interest, enjoyment, and perceived value of the subject. In this study, it is measured through students' responses to indicators such as: Enjoyment of mathematics, Interest and motivation, Perceived usefulness, and Confidence in learning mathematics.

Enjoyment in Mathematics. This refers to the level of pleasure or interest respondents experience when engaging in mathematical activities, as reflected in their responses to the enjoyment component of the attitude questionnaire.

Grade 9 Students. In the context of this research, they are enrolled under the K to 12 Basic Education Curriculum in public and private junior high schools for the school year 2025–2026 within the research locale who will participate as respondents.

Motivation in Mathematics. This refers to the respondents' willingness and drive to engage in learning mathematics and complete mathematical tasks, as measured by the motivation indicators in the

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survey.

Numeracy Skills. This refers to the Grade 9 students' ability to perform mathematical operations, interpret quantitative information, and apply problem-solving strategies aligned with the K to 12 Mathematics Curriculum of the Department of Education (DepEd). These skills will be measured using a researcher-made numeracy test based on competencies in algebra, geometry, and statistics for Grade 9.

Numeracy Skills Enhancement Plan. This refers to the intervention program proposed in the study to improve the numeracy skills and problem-solving confidence of Grade 9 students. Operationally, it includes structured and scaffolded mathematics activities aligned with the K–12 curriculum, with effectiveness measured through students' numeracy test scores and problem-solving confidence levels.

Problem-Solving Confidence. This term refers to the learners' self-assurance in handling mathematical problems as reflected in their willingness to attempt, persist, and complete problem-solving tasks. In this study, it will be measured using a Likert-scale questionnaire adopted from Gok (2012)

Self-Confidence in Mathematics. This refers to the respondents' perceived belief in their ability to understand and perform mathematical tasks, based on the self-confidence component of the attitude questionnaire.

Value of Mathematics. This refers to the extent to which respondents perceive mathematics as

useful, important, and relevant to daily life and future career, as measured by the value-of-math indicators in the survey.

Chapter 2 PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

This chapter presented the analyses and interpretations of the data gathered from the study which aimed to determine the profile of the respondents in terms of their age, gender, parents' highest educational attainment, and combined family monthly income. This also assessed the numeracy competence of the respondents through numeracy test, problem solving confidence and their attitudes towards mathematics in terms of self-confidence, value of math, enjoyment in math, and motivation math. Furthermore, the relationship of the respondents' numeracy competence and attitudes towards mathematics and [problem solving confidence was also considered.

With the help of the respondents' answers to the survey questionnaire, the following results and findings are hereby presented and discussed as follows:

PROFILE OF THE RESPONDENTS

This section presented the profile of the respondents in terms of their age, gender, parents' highest educational attainment, and combined family monthly income.

Table 5 - Age and Gender of the Respondents

Age (in years)	Female		Male		Total	
	f	%	f	%	f	%
16 and above	3	3.00	2	2.00	5	5.00
15	11	11.00	15	15.00	26	26.00
14	39	39.00	30	30.00	69	69.00
Total	53	53.00	47	47.00	100	100.00
Mean: 14.37	St.Dev. 0.61					

Age and gender are considered important variables that need to be determine in this study which could help in explaining the results of the study. Data gathered are presented in Table 5 below.

As shown in Table 5, there were 53 out of 100 respondents who are female students which comprised 53.00 percent of the respondents while there were 47 or 47.00 percent of them were male students. Thirty – nine or 39.00 percent of the female students were 14 years old followed by 11 or 11.00

percent of them were 15 years old. Moreover, there were 30 or 30.00 percent of the male respondents with of 14 years old and only fifteen or 15.00 percent of them had age 15 years old. It can be noted that the male respondents were older than the female respondents. However, the age of the respondents was within the expected age of the regular Grade 9 students. This implies that most of them had entered school on the proper age requirement by DepEd. Delaying the entry of students in school in order to

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have advantage on their peers or retaining them to a certain grade level to ensure that they have achieved at that level could be an impractical strategy to improve students' achievement. According to Orbeta et al. (2021), students are more likely the low performers because these are those who are retained or stopped schooling at certain levels.

Parents' Highest educational Attainment

Parent's highest educational attainment is an important demographic factor that may influence students' academic behavior and numeracy development. Understanding this profile variable helps in explaining possible variations in the study's results. Data gathered are presented in Table 6 below.

Table 6 - Parents' Highest Educational Attainment

Highest Educational Attainment	Father		Mother	
	f	%	f	%
Doctorate Graduate	2	2.00	2	2.00
With Doctorate Units	0	0.00	1	1.00
Master's Graduate	4	4.00	1	1.00
With Master's Units	2	2.00	4	4.00
College Graduate	58	58.00	68	68.00
College Level	12	12.00	9	9.00
High School Graduate	12	12.00	14	14.00
High School Level	7	7.00	1	1.00
Elementary Graduate	0	0.00	0	0.00
Elementary Level	2	2.00	0	0.00
No Formal Education	1	1.00	0	0.00
Total	100	100.00	100	100.00

Table 3 showed the distribution of parents' highest educational attainment as reported by the respondents. The results indicate that the majority of both fathers (58%) and mothers (68%) are college graduates, suggesting a generally well-educated parental population. Having a substantial number of parents who completed higher education may contribute to stronger academic support at home, as parents with higher educational attainment tend to value schooling and are more capable of assisting their children academically. According to Jin (2023), parental education remains one of the strongest predictors of student learning outcomes, as parents with college backgrounds often provide more structured learning environments.

Furthermore, a number of parents also reported being college level (fathers 12%; mothers 9%) or high school graduates (fathers 12%; mothers 14%). This indicates that although a significant portion attained tertiary education, there is still a notable group whose formal schooling stopped at secondary level. Research by Davis-Kean et al. (2021) emphasizes that parental education shapes the cognitive stimulation children receive at home, suggesting that differing educational backgrounds may lead to varied levels of academic engagement and support.

The table also shows a smaller percentage of parents holding postgraduate degrees (doctorate and master's), ranging from 1–4%. This group, though limited in number, may reflect families with strong academic orientation and higher educational

aspirations. A study by Bener et al. (2021) found that parents with advanced degrees demonstrate higher expectations for their children's educational performance, which often translates to more positive learner outcomes.

Very few parents completed only elementary education or had no formal schooling. While this represents a minor proportion of the sample, it is essential to recognize that parents with lower educational attainment may face challenges in providing academic assistance at home. Davis-Kean et al. (2021) argue that lower parental education is often associated with reduced confidence in guiding children's schoolwork, though it does not diminish their motivation to support their children.

In general, the results show that the respondents come from families where most parents have achieved higher levels of education, particularly college degrees. This may have positive implications for the learners' academic environments, as higher parental education is frequently associated with greater educational support, enhanced motivation, and stronger emphasis on schooling.

Combined Family Income

The respondents' monthly family income is a key socioeconomic variable that may affect learning opportunities, access to resources, and overall academic performance. This information helps contextualize the outcomes of the study. Data gathered are presented in Table 7 below.

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Table 7 - Respondents' Combined Family income

Description of Monthly Income	Monthly Income (in pesos)	f	%
High-income households	76,700 and above	15	15.00
Upper-middle-income households	between 43,829-76,699	18	18.00
Middle-income households	between 21,915-43,828	32	32.00
Lower-middle-income households	between 10,957-21,914	22	22.00
Low-income households	less than 10,957	13	13.00
Total		100	100.00

Table 7 showed the distribution of the respondents' combined family income. The results reveal that the largest proportion of respondents (32%) belong to families earning between ₱21,915–₱43,828 monthly, placing them within the lower-middle to middle-income bracket. Families in this range are generally able to meet basic needs but may still experience financial limitations in terms of educational expenses and enrichment activities. According to Catacutan et al. (2024), Filipino households within the middle-income spectrum often balance essential needs with limited discretionary spending, which may affect the level of educational support they can provide.

A substantial portion of the respondents also come from families earning ₱10,957–₱21,914 (22%), indicating that nearly one-fourth fall within lower-income categories. Families in this income range may face economic pressures that influence children's schooling experiences, such as limited access to learning materials at home. Mistry et al. (2021) found that financial strain can affect students' overall learning conditions, particularly in early childhood and elementary levels, where parental provision of resources plays a critical role.

Conversely, 15% of respondents belong to higher-income households earning ₱76,700 and above, while another 18% fall between ₱43,829–₱76,699. These groups represent upper-middle to high-income families who typically have greater financial capacity to support academic needs, such as supplemental learning programs, digital devices, or additional tutoring. Research by Paulus, Spinath, and Hahn (2021) emphasizes that higher socioeconomic

status is associated with greater access to educational opportunities and a more conducive home learning environment.

Meanwhile, 13% of the respondents belong to households earning less than ₱10,957, reflecting economically vulnerable families. Children from low-income households often encounter challenges related to resource availability, parental time for academic supervision, and stable learning routines. Xia (2024) assert that socioeconomic disadvantage can influence a child's academic readiness and engagement, although supportive school environments can help mediate these effects.

In general, the results indicate that the respondents come from diverse socioeconomic backgrounds. This range of financial conditions may influence the learners' access to academic resources, and overall educational experiences.

LEVEL OF RESPONDENTS' ATTITUDES TOWARDS MATHEMATICS

The overall attitude of students toward mathematics is a key affective factor that can influence their motivation, engagement, and academic performance. Assessing their general attitude provides a comprehensive understanding of how they perceive and respond to mathematical tasks.

Self-confidence

Self-confidence in mathematics reflects students' belief in their ability to perform mathematical tasks. Measuring this component of attitude helps explain its influence on numeracy competence. Data gathered are presented in Table 8.

Table 8 - Level of respondents' attitudes towards Mathematics in terms of self-confidence

S/N	Indicators	WM	SD	Verbal Description
1	Mathematics is a standout amongst my most feared subjects.	3.38	1.02	Neutral
2	My mind goes blank, and I am unable to think clearly when working with math.	3.10	1.06	Neutral
3	Studying mathematics makes me feel nervous.	2.77	1.17	Neutral
4	Mathematics makes me feel uncomfortable.	2.36	1.11	Negative
5	I am constantly under an awful strain in a math class.	2.71	1.08	Neutral
6	When I hear the word mathematics, I feel uneasy.	2.31	1.19	Negative
7	It makes me nervous to even think about completing a math problem.	2.73	1.35	Neutral
8	Mathematics does not scare me at all.	2.72	1.10	Neutral

Impact Factor:	ISRA (India)	= 6.317	SIS (USA)	= 0.912	ICV (Poland)	= 6.630
	ISI (Dubai, UAE)	= 1.582	ПИИИ (Russia)	= 0.191	PIF (India)	= 1.940
	GIF (Australia)	= 0.564	ESJI (KZ)	= 8.100	IBI (India)	= 4.260
	JIF	= 1.500	SJIF (Morocco)	= 6.004	OAJI (USA)	= 0.350

9	I expect to do well in any math class I take.	3.02	1.07	Neutral
10	I am constantly confused in my math class.	2.96	1.09	Neutral
11	I have a lot of self-confidence when it comes to mathematics.	2.62	1.07	Neutral
12	I am able to solve math problems without much difficulty.	2.73	1.21	Neutral
13	I feel insecure when trying to do mathematics.	3.00	1.23	Neutral
14	I learn mathematics easily.	2.82	1.05	Neutral
15	I believe that I am good at solving math problems.	2.78	1.10	Neutral
Aggregate Mean		2.80		Neutral
Aggregate Standard Deviation			1.13	

Legend: 4.21-5.00-Very Positive; 3.41-4.20- Positive ; 2.61-3.40-Neutral; 1.81-2.60-Negative;1.00-1.80-Very Negative

Table 5 showed the level of respondents’ attitudes towards Mathematics in terms of self-confidence. The results reveal that the overall aggregate mean of 2.80 indicates a Neutral attitude, suggesting that respondents neither strongly believe in nor strongly doubt their mathematical abilities. This neutrality reflects a balanced yet uncertain disposition toward mathematics, where learners experience both moments of confidence and hesitation.

The table further shows that several indicators—specifically items 4 (WM = 2.36) and 6 (WM = 2.31)—obtained Negative verbal descriptions. These indicators are negatively worded items expressing discomfort and uneasiness toward mathematics. Negative reactions such as these are common signs of mild math anxiety, characterized by feelings of discomfort and worry in math-related situations. According to Victor-Edema (2024), math anxiety continues to influence learners' emotional responses toward mathematics, often triggered by early experiences of difficulty or pressure in solving mathematical tasks.

On the other hand, the majority of the indicators—such as “Studying mathematics makes me nervous,” “I expect to do well in any math class,” and “I learn mathematics easily”- received Neutral ratings. This suggests that learners do not completely fear mathematics, but they are also not fully confident in their abilities. Neutrality in mathematical self-confidence reflects a transitional mindset where students may be open to improving but still lack consistent belief in their skills. In a study by Boaler (2022), students’ moderate confidence levels often stem from inconsistent learning experiences, where success in some areas of math is overshadowed by difficulty in more complex tasks.

Meanwhile, items that measure positive self-belief, such as “I believe that I am good at solving math problems” (WM = 2.78) and “I have a lot of self-confidence when it comes to mathematics” (WM = 2.62), also fall under the Neutral category. This implies that while students do not explicitly perceive themselves as weak in mathematics, they have not yet developed strong confidence in their mathematical capabilities. Fitz and Price (2025) emphasize that developing strong mathematical self-concept requires continuous reinforcement, positive learning experiences, and supportive instructional practices.

In general, the results show that respondents hold a Neutral level of self-confidence in mathematics. This may mean that learners do not exhibit strong anxiety, but they also lack the firm confidence needed to excel in mathematical tasks. Research by Brewster (2023) highlights that students with moderate or neutral math self-confidence often benefit significantly from instructional strategies that build assurance, such as mastery-based learning and scaffolded problem-solving activities.

Overall, these findings suggest that while respondents do not fear mathematics intensely, there remains a need to strengthen their confidence and reduce lingering feelings of discomfort, especially among learners who reported negative reactions toward mathematical tasks.

Value of Mathematics

The value students place on mathematics indicates their perception of the subject’s importance and usefulness. This dimension is essential in understanding motivation and engagement. Data gathered are presented in Table 9 below.

Table 9 - Level of respondents attitudes towards Mathematics in terms of Value of Mathematics

S/N	Indicators	WM	SD	Verbal Description
1	Mathematics is an essential and necessary subject.	4.12	1.08	Positive
2	I want to develop my mathematical skills.	4.54	0.81	Very Positive
3	Mathematics helps develop the mind and teaches us to think.	4.19	0.83	Positive
4	Mathematics is essential in everyday life.	3.88	1.06	Positive

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	GIF (Australia)	= 0.564	ESJI (KZ)	= 8.100	IBI (India)	= 4.260
	JIF	= 1.500	SJIF (Morocco)	= 6.004	OAJI (USA)	= 0.350

5	Mathematics is one of the most important subjects for people to study.	4.10	0.86	Positive
6	High school math courses would be useful regardless of my career path.	4.01	0.97	Positive
7	I can think of many ways that I use math outside of school.	3.61	1.09	Positive
8	Studying advanced mathematics is useful.	4.06	0.97	Positive
9	Studying math helps me with problem-solving in other areas.	3.93	0.91	Positive
10	A solid math foundation could help me in my professional life.	4.00	0.93	Positive
Aggregate Mean		4.04		Positive
Aggregate Standard Deviation			0.95	

Table 9 showed the level of respondents' attitudes towards Mathematics in terms of the value of math. The table reveals an aggregate mean of 4.04, which corresponds to a Positive verbal description. This indicates that respondents generally recognize the importance, usefulness, and relevance of mathematics in both academic and real-life contexts.

The results show that respondents strongly acknowledge mathematics as beneficial, especially with Item 2 (WM = 4.54) obtaining a Very Positive rating. This reflects a strong desire among learners to further develop their mathematical skills. According to Morano et al. (2023), students' motivation to enhance mathematical abilities is closely linked to their belief in math's long-term usefulness and its role in cognitive development.

Most indicators, such as "Mathematics is an essential subject," "Mathematics helps develop the mind," and "Math is essential in everyday life", received Positive responses. These items highlight the respondents' awareness of math's significance across various domains. In the study of DiNapoli and Miller (2022), students who perceive mathematics as valuable tend to demonstrate greater engagement and persistence when solving mathematical tasks because they believe math contributes directly to critical thinking and logical reasoning.

Responses also show a strong acknowledgment of math's role beyond school settings. For instance, Item 7 (WM = 3.61) indicates that many respondents can identify ways they apply math in daily situations, such as budgeting, measuring, and interpreting information. This is consistent with the findings of

Morano et al. (2023), who reported that students' real-world experiences significantly influence their appreciation of math's practicality.

Moreover, respondents expressed positive attitudes toward the importance of mathematics in future careers, with items such as "A solid math foundation could help me in my professional life" (WM = 4.00) and "High school math courses are useful regardless of my career path" (WM = 4.01). Tan and Lim (2024) emphasize that learners who view math as essential to their future employment are more likely to engage deeply with mathematical content and see its long-term relevance in a global workforce increasingly dependent on quantitative skills.

In general, the results show that respondents highly value mathematics, recognizing both its academic benefits and its application in everyday life. This positive perception may reflect the effectiveness of classroom instruction, increased exposure to real-life math applications, and growing awareness of math's relevance across careers and life situations. Such valuing of mathematics is essential, as noted by Roche et al. (2023), who argue that students who appreciate the relevance of mathematics are more likely to approach the subject with confidence, motivation, and sustained interest.

Enjoyment in Mathematics

Enjoyment in mathematics represents the emotional aspect of learning the subject, which may significantly influence performance and persistence. This indicator is examined to determine its contribution to numeracy outcomes. Data gathered are presented in Table 10 below.

Table 10 - Level of respondents attitudes towards Mathematics in terms of Enjoyment in Mathematics

S/N	Indicators	WM	SD	Verbal Description
1	I get much satisfaction out of solving a math problem.	3.60	1.23	Positive
2	I have generally enjoyed studying math in school.	3.14	0.96	Neutral
3	Mathematics is dull and boring.	2.11	0.89	Negative
4	I like to tackle new problems in mathematics.	2.88	1.03	Neutral

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	JIF	= 1.500	SJIF (Morocco)	= 6.004	OAJI (USA)	= 0.350
5	I would rather complete a task in math than write an essay.	2.80	1.44	Neutral		
6	I like mathematics.	3.13	1.13	Neutral		
7	I am happier in a mathematics class than in any other class.	2.68	1.08	Neutral		
8	Mathematics is an interesting subject.	3.81	0.92	Positive		
9	I am comfortable expressing my own ideas on how to solve a difficult math problem.	2.74	1.02	Neutral		
10	I am comfortable answering questions in math.	2.92	0.93	Neutral		
Aggregate Mean		2.98		Neutral		
Aggregate Standard Deviation			1.06			

Table 10 showed the level of respondents' attitudes towards Mathematics in terms of enjoyment in math. The table reveals an aggregate mean of 2.98, which corresponds to a Neutral verbal description. This suggests that respondents neither strongly enjoy nor strongly dislike mathematics. Their attitudes reflect a moderate stance where some aspects of math are appealing, while others may still pose challenges or discomfort.

The results show that the highest-rated indicators—Item 1 (WM = 3.60) and Item 8 (WM = 3.81)—obtained Positive descriptions. These items highlight that many respondents find satisfaction in solving math problems and consider mathematics an interesting subject. Students who perceive problem-solving as enjoyable often experience deeper engagement and persistence. According to Jones (2023), enjoyment in academic tasks enhances intrinsic motivation, allowing learners to sustain interest even when tasks become more challenging.

However, the findings also show that Item 3 (WM = 2.11) received a Negative rating, reflecting that some students still see mathematics as dull or boring. Negative perceptions like these may stem from past difficulties or teaching approaches that do not align with students' preferred learning styles. Anh and Duong (2023) found that students' enjoyment of mathematics significantly increases when learning experiences are interactive, meaningful, and connected to real-life contexts.

Most of the items—including “I have generally enjoyed studying math,” “I like mathematics,” “I am happier in a mathematics class,” and “I am comfortable answering questions in math”—received Neutral ratings. This suggests that while students

acknowledge some positive aspects of mathematics, they do not consistently experience enjoyment or comfort in math-related activities. Neutral responses often indicate inconsistent experiences, where students may enjoy mathematical activities under certain conditions but struggle in others. In the study of Hettinger et al. (2023) students with moderate enjoyment in math tend to fluctuate in engagement depending on task difficulty, classroom climate, and the support they receive from their teachers.

Additionally, the neutral ratings on items related to participation—such as expressing ideas during problem solving or answering questions in class—imply that students may still lack full confidence in contributing during math discussions. Aulia (2024) emphasized that classroom environments that encourage risk-taking and value student reasoning significantly increase enjoyment and willingness to participate.

In general, the results show that respondents have a neutral level of enjoyment in mathematics. This indicates that while students recognize the interesting and satisfying aspects of math, they do not consistently experience joy or comfort in mathematical activities. As noted by Sujatha and Vinayakan (2023), fostering enjoyment in math requires engaging instructional strategies, supportive classroom interactions, and opportunities for students to experience meaningful mathematical success.

Motivation in Mathematics

Motivation in mathematics reflects the level of effort students are willing to exert when engaging with mathematical tasks. Assessing this factor helps clarify its role in developing numeracy skills. Data gathered are presented in Table 11 below.

Table 11 - Level of respondents attitudes towards Mathematics in terms of Motivation in Mathematics

S/N	Indicators	WM	SD	Verbal Description
1	I am confident that I could learn advanced mathematics.	2.85	1.16	Neutral
2	I would like to avoid using mathematics in school.	2.28	1.00	Negative
3	I will take more than the required number of mathematics subjects.	2.50	0.85	Negative
4	I plan to take as much mathematics as I can during my education.	3.01	0.97	Neutral

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	JIF	= 1.500	SJIF (Morocco)	= 6.004	OAJI (USA)	= 0.350
5	The challenge of mathematics appeals to me.		3.22	0.94	Neutral	
	Aggregate Mean					
			2.77		Neutral	
	Aggregate Standard Deviation			0.98		

Table 11 showed the level of respondents' attitudes towards Mathematics in terms of motivation in math. The table reveals an aggregate mean of 2.77, which corresponds to a Neutral verbal description. This indicates that the respondents exhibit a moderate level of motivation toward learning mathematics. They do not fully avoid the subject, yet they are not highly driven to pursue extensive math learning beyond what is required.

Two indicators—Item 2 (WM = 2.28) and Item 3 (WM = 2.50)—obtained Negative verbal descriptions. These negatively worded indicators suggest that some respondents prefer to avoid using mathematics in school and are not inclined to take more math subjects beyond the required courses. Negative motivation may stem from previous challenging experiences or perceived difficulty in understanding mathematical concepts. According to Aguilar (2021), students with low motivation in mathematics often report anxious or discouraging learning experiences that affect their willingness to engage further with the subject.

Meanwhile, most indicators—including “I am confident that I could learn advanced mathematics” (WM = 2.85), “I plan to take as much mathematics as I can during my education” (WM = 3.01), and “The challenge of mathematics appeals to me” (WM = 3.22)—received Neutral descriptions. These responses indicate a balanced but uncertain level of motivation, where students recognize the value of mathematics but may still be hesitant about

committing deeper effort. Hettinger et al. (2023) found that students' math motivation is strongly influenced by classroom climate and instructional support; when learners feel encouraged and supported, they show greater willingness to persist in mathematical tasks.

Items showing neutrality also highlight that respondents do not reject the idea of pursuing more advanced mathematics, but they are not strongly compelled either. This middle-ground perspective often reflects students' fluctuating confidence and varying levels of self-efficacy. In the study of Roche et al. (2021), moderate motivation in mathematics is commonly observed when learners perceive the subject as important but also challenging, resulting in a cautious approach to further mathematical engagement.

In general, the results show that respondents hold a Neutral level of motivation toward mathematics. This means that while they are open to learning and can appreciate the challenge of the subject, they do not demonstrate strong enthusiasm toward taking more math courses or integrating mathematics deeply into their educational plans. As emphasized by Siregar (2025), strengthening students' motivation requires meaningful learning experiences, supportive feedback, and opportunities to succeed in challenging tasks, all of which help students develop greater persistence and interest in mathematics.

Table 12 - Summary on the level of respondents Attitudes towards Mathematics

Components	WM	SD	Verbal Description
Self-confidence	2.80	1.13	Neutral
Value of Math	4.04	0.95	Positive
Enjoyment in Math	2.98	1.06	Neutral
Motivation in Math	2.77	0.98	Neutral
Grand Mean	3.15		
Grand Standard Deviation		1.03	Neutral

Table 12 presented the summary of respondents' attitudes towards Mathematics across four components—self-confidence, value of math, enjoyment in math, and motivation in math. The table reveals a Grand Mean of 3.15, which corresponds to a Neutral verbal description. This indicates that overall, the respondents exhibit a balanced but moderate attitude toward mathematics, showing neither strong

negativity nor strong positivity, except in their valuation of the subject.

The findings show that Value of Math obtained the highest weighted mean (WM = 4.04, Positive). This indicates that respondents clearly recognize the importance and usefulness of mathematics in education, daily life, and future careers. According to Hill et al. (2023), students who value mathematics

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tend to see its relevance beyond the classroom, contributing to stronger appreciation and long-term engagement with the subject.

Meanwhile, the components of Self-confidence (WM = 2.80), Enjoyment in Math (WM = 2.98), and Motivation in Math (WM = 2.77) all yielded Neutral descriptions. These results suggest that respondents hold moderate beliefs about their abilities, experience a fair amount of enjoyment, and possess an average level of motivation when dealing with mathematical tasks. Neutral attitudes reflect inconsistencies in experiences—where students may feel confident or motivated in some mathematics topics but not in others. In a study by Augilar (2021), students' mixed experiences in mathematics often lead to fluctuating confidence and motivation, particularly when they encounter varying levels of difficulty across topics.

The neutral ratings for enjoyment and motivation also imply that while students do not strongly dislike mathematics, they are not fully enthusiastic about pursuing it either. Liu et al. (2022) highlighted that students with moderate enjoyment tend to participate more when learning environments are supportive and tasks are meaningful. Likewise,

Morano et al. (2021). found that moderate motivation is typical among learners who perceive mathematics as valuable but challenging, resulting in cautious engagement rather than strong proactive involvement.

Overall, the Grand Mean of 3.15 indicates a generally Neutral attitude toward mathematics. This means that although students recognize the importance of mathematics, they do not consistently feel confident, motivated, or highly joyful when engaging with mathematical tasks. As emphasized by Sujatha and Vinayakan (2023), strengthening positive attitudes in mathematics requires instructional practices that foster success experiences, provide supportive feedback, and connect mathematical ideas to real-life applications.

LEVEL OF PROBLEM SOLVING CONFIDENCE OF THE RESPONDENTS

Problem-solving confidence indicates students' perceived ability to analyze and solve mathematical problems. Understanding this variable is crucial in interpreting students' numeracy performance. Data gathered are presented in Table 13 below.

Table 13 - Level of problem-solving confidence of the respondents

S/N	Indicators	WM	SD	Verbal Description
1	I like to solve to a problem	3.10	1.06	Moderate
2	I enjoy solving a problem	3.10	1.07	Moderate
3	I like to solve a numeric problem	2.96	1.01	Moderate
4	I do my best to be successful in problem solving	3.90	0.87	High
5	I am interested in problem solving	3.28	0.98	Moderate
6	I like to struggle with solving problem even if I cannot solve the problem	3.14	1.16	Moderate
7	I like to solve problems from different sources	3.00	1.01	Moderate
8	I struggle with a problem until I find the correct answer	3.70	0.86	High
9	I try too hard when I cannot solve the problem	3.60	1.06	High
10	I am sure that I can solve a problem	2.84	1.13	Moderate
11	I am self confident in problem solving	2.81	1.08	Moderate
12	I am sure that I am able to solve even a difficult problem	2.57	1.12	Low
13	I do my best for solving the problem no matter how difficult a problem	3.79	0.88	High
14	I lose track of time while solving a problem	3.58	1.14	High
15	I demoralize if I cannot solve a problem	2.97	1.03	Moderate
16	I am stressed while solving a problem	3.38	1.09	Moderate
17	I lose self-confidence if I cannot solve a problem	3.35	1.40	Moderate
18	I am upset when I find incorrect answer of a problem	3.42	1.26	High
19	I am afraid of making numerical mistakes	3.67	1.09	High
20	Preconceptions prevent me from solving a problem	2.92	0.85	Moderate
Aggregate Mean		3.25		
Aggregate Standard Deviation			1.06	Moderate

Legend: 4.21-5.00-Very High; 3.41-4.20- High; 2.61-3.40-Moderate; 1.81-2.60-Low; 1.00-1.80- Very Low

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Table 13 showed the level of problem-solving confidence of the respondents. The table reveals an aggregate mean of 3.25, which corresponds to a Moderate verbal description. This indicates that respondents generally possess a fair level of confidence in solving mathematical problems, though not at a consistently high level. Their responses suggest that while they demonstrate persistence and interest in problem solving, they also experience uncertainty, stress, and occasional loss of self-confidence.

Several indicators obtained High verbal descriptions, particularly items related to perseverance and emotional investment in problem solving. For instance, respondents highly agreed that they do their best to be successful in problem solving (WM = 3.90), struggle with a problem until they find the correct answer (WM = 3.70), and try very hard when they cannot solve a problem (WM = 3.60). These findings illustrate students' determination and resilience when faced with challenging tasks. According to DiNapoli and Miller (2022), students who show strong perseverance in problem solving are more likely to develop adaptive learning behaviors, enabling them to approach tasks with greater persistence and belief in improvement.

Additionally, respondents rated highly their emotional reactions toward errors, such as being upset when they find incorrect answers (WM = 3.42) and being afraid of making numerical mistakes (WM = 3.67). These high ratings suggest that while students are committed to solving problems correctly, they may also experience performance pressure. Hoth et al. (2022) found that fear of making mistakes is common among math learners and can influence their confidence, especially when they value accuracy and correctness.

The majority of items, however, received Moderate ratings. These include statements such as liking to solve numeric problems, being sure they can solve a problem, being self-confident in problem

solving, and experiencing stress while solving problems. Moderate responses indicate that students possess a balanced level of problem-solving confidence—sufficient to engage with mathematical tasks but not consistently strong across all problem types. Wang and Molnár (2023). explain that moderate problem-solving confidence typically emerges when students have mixed experiences, alternating between success and difficulty depending on problem complexity and prior knowledge.

One item received a Low verbal description: “I am sure that I am able to solve even a difficult problem” (WM = 2.57). This suggests that respondents may struggle with confidence when faced with more complex mathematical challenges. This aligns with the findings of Monarrez and Tchoshanov (2024), who reported that students often show lower confidence for high-cognitive-demand tasks, especially when they lack familiarity or feel pressured to perform well.

In general, the results show that respondents have a Moderate level of problem-solving confidence. This means that while they demonstrate persistence, determination, and interest in solving mathematical problems, they also encounter challenges related to stress, fear of mistakes, and reduced confidence when dealing with more difficult problems. As emphasized by Siregar (2025), strengthening problem-solving confidence requires supportive learning environments, opportunities for guided struggle, and instructional strategies that build students' belief in their ability to succeed even when tasks are complex.

LEVEL OF NUMERACY SKILLS OF THE RESPONDENTS

Numeracy skills measure students' competence in performing essential mathematical tasks. This variable is central to the study's objectives and helps identify learners' proficiency levels. Data gathered are presented in Table 14 below.

Table 14 - Level of numeracy skills of the respondents

Level	Numerical Range	f	%
Advanced	33–40	3	3.00
Proficient	25–32	11	11.00
Basic	17–24	48	48.00
Developing	9–16	35	35.00
Beginning	0–8	3	3.00
Total		100	100.00
Mean			18.45
St. Dev.			5.67

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	GIF (Australia)	= 0.564	ESJI (KZ)	= 8.100	IBI (India)	= 4.260
	JIF	= 1.500	SJIF (Morocco)	= 6.004	OAJI (USA)	= 0.350

Table 14 showed the level of numeracy skills of the respondents. The results indicate that the majority of learners (48%) fall within the Basic level, demonstrating foundational numeracy skills but still requiring support to perform more complex mathematical operations. Numeracy skills are essential for applying mathematical concepts in everyday life and academic tasks, as they involve understanding, interpreting, and manipulating numbers effectively. According to Aniasi et al. (2022), students with basic numeracy skills often face challenges in problem solving and higher-order mathematical reasoning, which may limit their capacity to perform confidently in more advanced topics.

A significant portion of the respondents, 35%, are classified under the Developing level, suggesting that they are still acquiring essential skills needed for competence in mathematics. Only a small proportion of respondents achieved higher performance levels: 11% are Proficient, and 3% are Advanced, reflecting that a limited number of learners can confidently perform complex calculations and problem-solving tasks. Sujatha and Vinayakan (2023) emphasize that students with advanced numeracy skills are better equipped to handle academic challenges and real-life quantitative reasoning, highlighting the importance of strengthening foundational skills for all learners.

Conversely, 3% of respondents belong to the Beginning level, indicating minimal numeracy competency and a need for focused intervention. Early identification and remediation are critical in

preventing further difficulties in mathematics, as noted by Bryant et al. (2019), who found that targeted numeracy support significantly improves learners' performance and confidence in mathematics.

The mean score of 18.45, which falls within the Basic range, coupled with a standard deviation of 5.67, indicates that while most students perform at a foundational level, there is considerable variability in numeracy skills among the respondents. This suggests that instructional strategies should be differentiated to cater to varying levels of ability, ensuring that both struggling and high-performing learners are adequately supported.

In general, the results reveal that respondents exhibit a Basic level of numeracy skills overall. This implies a need for interventions, such as guided practice, problem-solving activities, and scaffolded instruction, to strengthen learners' numerical competencies. As emphasized by Chen (2025), enhancing numeracy skills in early education promotes academic achievement, confidence in mathematics, and the ability to apply mathematical reasoning in real-life contexts.

RELATIONSHIP BETWEEN ATTITUDE TOWARDS MATHEMATICS AND NUMERACY SKILLS OF THE RESPONDENTS

This section presents the relationship between the respondents' attitude towards Mathematics and their numeracy skills which is presented in table 15.

Table 15 - Test of relationship between the respondents' attitudes towards Mathematics and their numeracy skills

Variables	Spearman's rho	Strength of Correlation	p - value	Decision	Result
Attitudes and Numeracy Skills	0.168	Negligible Positive	0.094	Do not reject Ho	Not Significant

*significant at $p < 0.05$ (two-tailed)

Table 15 showed the test of relationship between the respondents' attitudes towards Mathematics and their numeracy skills. The results indicate a Spearman's rho of 0.168, which reflects a negligible positive correlation between attitudes and numeracy skills. This suggests that while more positive attitudes toward mathematics are slightly associated with higher numeracy skills, the relationship is very weak and practically minimal. The p-value of 0.094 exceeds the significance threshold of 0.05, leading to the decision to not reject the null hypothesis. This means that the observed correlation is not statistically significant, and the data do not provide enough evidence to conclude a meaningful relationship

between respondents' attitudes and their numeracy performance.

The negligible positive correlation may be attributed to the fact that although learners recognize the value of mathematics and hold generally neutral attitudes toward enjoyment, confidence, and motivation, these attitudes do not automatically translate into measurable numeracy skills. According to Rehman (2025), while positive attitudes can influence engagement in learning, actual proficiency in numeracy also depends heavily on prior knowledge, instructional quality, and practice opportunities. Similarly, Wen et al. (2022) emphasized that students may value mathematics and

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display interest, but without consistent application and skill development, attitudes alone have limited impact on numerical performance.

In general, the results imply that respondents' attitudes toward mathematics are not significantly related to their numeracy skills. This indicates that fostering positive attitudes alone may not be sufficient to improve numeracy; targeted instruction, guided practice, and skill-building exercises are also essential to enhance students' mathematical competence. As noted by Susanti (2025), effective numeracy

development requires a combination of positive learner disposition, deliberate practice, and contextualized problem-solving activities to achieve measurable improvement.

RELATIONSHIP BETWEEN PROBLEM SOLVING CONFIDENCE AND NUMERACY SKILLS OF THE RESPONDENTS

This section presents the relationship between the respondents' problem-solving confidence and their numeracy skills, which is presented in Table 16.

Table 16 - Test of the relationship between the respondents' problem-solving confidence and their numeracy skills

Variables	Spearman's rho	Strength of Correlation	p - value	Decision	Result
Problem Solving and Numeracy Skills	0.202*	Negligible Positive	0.044	Reject Ho	Significant

*significant at $p < 0.05$ (two-tailed)

Table 16 showed the test of the relationship between the respondents' problem-solving confidence and their numeracy skills. The results indicate a Spearman's rho of 0.202, reflecting a negligible positive correlation between problem-solving confidence and numeracy skills. Despite being categorized as negligible, the correlation is statistically significant with a p-value of 0.044, which is less than the 0.05 threshold, leading to the decision to reject the null hypothesis. This suggests that respondents' confidence in problem-solving is positively associated with their numeracy performance, albeit weakly.

The positive relationship implies that learners who demonstrate higher problem-solving confidence are more likely to perform better in numeracy tasks. Confidence in problem-solving enables students to approach mathematical problems with persistence, strategic thinking, and reduced anxiety, which can enhance performance. According to Torres-Peña (2025), students with strong problem-solving confidence are more likely to engage deeply in numerical reasoning and apply strategies effectively, thereby improving their numeracy outcomes. Similarly, Siregar (2025) emphasized that confidence in problem-solving acts as a motivational and cognitive resource that supports learners' ability to handle complex mathematical tasks.

In general, the results suggest that problem-solving confidence has a significant, albeit small, positive effect on numeracy skills. This finding highlights the importance of fostering problem-solving confidence in learners, as even slight increases in confidence can contribute to better numerical

performance. As noted by Clemente et al. (2024), interventions that build students' self-efficacy in problem solving—such as scaffolded tasks, guided practice, and constructive feedback—can enhance both confidence and competence in numeracy.

Chapter 3 SUMMARY, FINDINGS, CONCLUSION, AND RECOMMENDATION

This chapter presented the summary, findings, conclusion, and recommendations of the study. It aimed to provide a coherent overview of the respondents' attitudes toward mathematics, problem-solving confidence, numeracy skills, and the relationships among these variables, as a basis for a proposed intervention plan to improve mathematical performance.

SUMMARY

This study aimed to determine the attitudes and performance of students in mathematics, focusing on their self-confidence, perceived value of math, enjoyment, motivation, problem-solving confidence, and numeracy skills. The respondents' profiles, including parents' educational attainment and monthly income, were considered to provide context for interpreting the results. Data were gathered using a structured questionnaire designed to measure students' attitudes toward mathematics and their level of problem-solving confidence, alongside a standardized numeracy test to evaluate their mathematical skills. The study employed descriptive statistical tools such as frequency counts, percentages, weighted means, and standard deviations to summarize and describe the respondents' profiles and

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levels of attitudes, confidence, and numeracy skills. To determine the relationships among students' attitudes toward mathematics, problem-solving confidence, and numeracy skills, Spearman's rho correlation analysis was utilized.

The findings generated from these analyses served as the basis for interpreting the extent to which affective factors relate to students' mathematical performance and for formulating recommendations and an enhancement plan aimed at improving numeracy skills and problem-solving confidence among learners.

FINDINGS

The following findings were arrived based on the results of the data that were gathered and treated statistically.

Findings showed Majority of the respondents are male repeaters who are aging from fourteen to fifteen years old of Grade 9. Analysis of the respondents' profiles revealed that most respondents' fathers attained a college level of education, while most mothers achieved college graduation. A majority of families have a moderate monthly income. These findings suggest that while educational attainment and family income may provide some support for learning, they do not guarantee high mathematical performance.

In terms of attitudes toward mathematics, respondents showed a Neutral level of self-confidence, indicating moderate belief in their mathematical abilities. However, they recognized the importance of mathematics in daily life and education, with a Positive rating in the value of math. Enjoyment of mathematics and motivation to engage in mathematical tasks were both Neutral, reflecting moderate interest and willingness to participate in learning activities. Overall, the respondents hold a Neutral attitude toward mathematics, appreciating its relevance but not consistently demonstrating confidence, enjoyment, or motivation.

Regarding problem-solving confidence, respondents generally displayed a Moderate level. Items assessing perseverance, such as struggling until finding the correct answer and doing their best in solving problems, received High ratings, demonstrating resilience and persistence in mathematical tasks. Conversely, items related to confidence in solving difficult problems scored lower, suggesting that respondents may experience uncertainty or stress in more challenging scenarios.

Chapter 4

OUTPUT OF THE STUDY

This chapter presented the numerical skills enhancement plan which aims to enhance the problem-solving confidence, attitudes, and numeracy skills of students in mathematics.

Assessment of numeracy skills revealed that the majority of respondents are at the Basic level, followed by Developing, with only a small fraction achieving Proficient or Advanced levels. The mean score indicates foundational mathematical abilities, with a standard deviation reflecting variability in performance. These results suggest that many students require additional support to develop higher-level numeracy skills.

The relationship tests showed that respondents' attitudes toward mathematics and numeracy skills are not significantly correlated, indicating that positive attitudes alone do not guarantee higher numeracy performance. In contrast, problem-solving confidence and numeracy skills demonstrated a negligible but significant positive correlation, suggesting that students who exhibit higher confidence in solving problems tend to perform slightly better in numeracy tasks.

CONCLUSION

Based on the findings, it can be concluded that respondents generally hold a Neutral attitude toward mathematics, with recognition of its value but moderate confidence, enjoyment, and motivation. Their problem-solving confidence is moderate, with strong persistence in manageable tasks but lower assurance when facing difficult problems. Numeracy skills are largely at the Basic level, indicating a need for additional instructional support. While attitudes toward mathematics do not significantly influence numeracy performance, problem-solving confidence shows a small positive effect, highlighting the importance of fostering self-efficacy and persistence in learning. Overall, the study suggests that factors such as skill development, confidence building, and instructional support are critical in enhancing mathematical performance.

RECOMMENDATION

Drawn from the study's findings and conclusion, it is highly recommended that the numerical skills enhancement plan to enhance the attitudes, problem-solving confidence, and numeracy skills of the respondents in mathematics be adopted. The plan should include activities and strategies that foster student-centered learning, build confidence in problem solving, and strengthen foundational numeracy skills to improve overall mathematical performance.

Rationale

The role of the teacher in the classroom extends beyond identifying high-performing students; it also includes recognizing and supporting learners who struggle during the learning process. Oftentimes, students with lower performance are left behind due to the limited time allocated for lessons. This practice

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can hinder learning, especially for students who find mathematics challenging. Mathematics is frequently considered a difficult subject because it requires the application of cumulative concepts and problem-solving strategies. The nature of the subject, which often relies on scaffolding, necessitates that students master foundational concepts before moving on to more complex topics. Failure to ensure a strong foundation may result in poor performance, and in some cases, student retention if learning deficits persist into subsequent grading periods.

The findings of this study indicate that while students recognize the value of mathematics and demonstrate moderate problem-solving confidence, most possess basic numeracy skills and hold neutral attitudes toward self-confidence, enjoyment, and motivation. These results highlight the need for an intervention that strengthens numeracy competence, problem-solving confidence, and positive engagement with mathematics. Addressing these areas is essential to reduce academic struggles, foster mathematical skills, and ultimately minimize student retention, which has remained a persistent issue in schools when learners fail to meet DepEd standards.

The numerical skills enhancement plan is designed to provide structured, student-centered activities that improve problem-solving confidence, enhance attitudes toward mathematics, and strengthen numeracy skills. Activities will focus on guided problem-solving, scaffolded practice, real-life applications, and collaborative learning, allowing students to actively engage in tasks while receiving continuous support and feedback. The intervention will also include exercises aimed at building self-confidence, helping students tackle challenging problems without fear of failure, and recognizing the importance of mathematics in daily life.

Objectives

The Numerical Skills Enhancement Plan is designed to achieve the following objectives:

1. Increased students' performance in Mathematics, particularly in numeracy skills
2. A student-centered classroom environment that fosters participation, engagement, and collaboration.
3. Improved attitudes toward mathematics, including enjoyment, confidence, and motivation.
4. Enhanced self-confidence in approaching and solving math-related activities.
5. Development of a sense of the importance of mathematics in real-life situations, reinforcing the practical value of the subject.

Scheme of the Implementation

To ensure that this enhancement plan is properly implemented, it will first be presented to the principal, guidance coordinators, and mathematics teachers of the school. Teachers will receive copies of the proposed activities, instructional matrices, and guidelines for implementation.

The plan will be executed in the classroom through structured, scaffolded lessons and collaborative problem-solving activities, ensuring that students at the basic and developing levels receive additional support. Teachers will provide continuous feedback, monitor student progress, and adapt tasks to address learners' specific needs.

Finally, the effectiveness of the enhancement plan will be evaluated based on improvements in numeracy skills, problem-solving confidence, and attitudes toward mathematics, allowing adjustments to the plan for maximum impact. Through this intervention, students are expected to gain confidence, strengthen their mathematical skills, and engage more actively in learning, thereby reducing difficulties in mathematics and improving overall performance.

Table 17 - Enhancement Plan: Fostering Positive Attitudes, Problem-Solving Confidence, and Numeracy Skills in Grade 9 Learners

Component	Objective	Strategy	Responsible	Budget	Source of Budget	Time Frame	Expected Outcome	Actual Accomplishment	Remarks
Attitude Enhancement	Improve students' attitudes toward	Workshops on math appreciation sessions	Math Teachers, Guidance Counselors	₱8,000	School Funds	1st Quarter SY 2026–27	Increased positive attitudes toward math		

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	mathematics								
Problem-Solving Confidence	Build confidence in solving mathematical problems	Guided problem-solving sessions, real-life math applications	Math Teachers, Grade Level Heads	₱10,000	School Funds	Monthly Sessions	Students demonstrate higher confidence in tackling problems		
Numeracy Skills Development	Strengthen foundational numeracy skills	Diagnostic tests, targeted practice exercises.	Math Teachers, Learning Support Staff	₱12,000	School Funds	Every Mid-Quarter	Improvement in numeracy test scores		
Engagement & Motivation	Increase student participation and enjoyment in math	Math games, interactive lessons, project-based learning	Math Teachers, ICT Staff	₱6,000	School Improvement Fund	Monthly	Students actively participate and show enthusiasm in math activities		
Feedback & Assessment	Monitor progress and provide support	Continuous assessment, reflection journals, teacher feedback	Math Teachers, Grade Level Coordinators	₱4,000	School Funds	End of Each Term	Data-driven adjustments to learning strategies		
Parent & Community Involvement	Strengthen home-school support	Parent-teacher conferences, progress updates	Homeroom Teachers, Guidance Office	₱5,000	PTA	Ongoing	Improved parent engagement and continuity of support		
Resource Development	Provide accessible instructional materials	Development of visual aids, ICT-based resources	Math Teachers, ICT Staff	₱7,000	School Improvement Fund	Monthly	Availability of learner-friendly math materials		

ACKNOWLEDGMENT

First, I would like to give thanks and praise to the Almighty God for providing me with wisdom and knowledge in this milestone. Second, my deepest and sincerest gratitude to all the people who helped me, in any manner by sharing their effort, knowledge, guidance, support, inspiration, and encouragement to make this research a success, namely:

Dr. Maria Salud M. Delos Santos, Chairman, for her insights and approval of this study;

Dr. Emerson D. Peteros, my thesis adviser, for sharing his time and expertise, valuable comments, and suggestions, and for giving me direction in the fulfillment of this research;

Members of the panel, **Dr. Reylan G. Capuno**, **Dr. Raymond C. Espina**, **Dr. Randy C. Mangubat**, **Dr. Jonathan O. Etcuban**, and **Dr. Veronica O. Calasang** for their brilliant comments and suggestions for the improvement of the study;

Mrs. Epifania M. Reyes, the Principal of St. Cecilia's College, for her guidance and allowing me to conduct this study;

The students and teachers at St. Cecilia's College in Poblacion Ward II, Minglanilla, Cebu, for their cooperation and support during the data gathering stage.

Rose Gamboa

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DEDICATION

This research is dedicated to my family for the never-ending inspiration.

To my parents, though you may not have supported me financially, your love, presence, and unwavering support have inspired me to strive harder. This dream is not only mine but also yours. Despite all the hardships and struggles we have faced, I continue to pursue my goals because of you. You are my greatest inspiration to dream beyond what I thought was possible.

To my working besties—Daddy, Ate Ching, and Thalia—thank you for helping me with my data gathering. Everything went smoothly and easily because of your support.

To all my friends, for always believing in me; thank you for walking beside me, for the cheers, and

your mere existence to support me in many little ways you never know of. Thank you,

To my research adviser, thank you for your patience, encouragement, and constant guidance. Your support has shaped this research into what it is today.

To my mentors, whose guidance and wisdom have inspired me to reach higher—this work is a reflection of your influence.

Above all, to the Almighty Father, thanks to you for the enlightenments, through all my prayers and granting me the strength, wisdom and grace to complete this thesis, this achievement is for Your glory.

Rose S. Gamboa

APPENDICES

Appendix A TRANSMITTAL LETTER

Dear Parents:

To God be the Glory!

Your child is invited to participate in a thesis entitled **"UNDERSTANDING STUDENTS' NUMERACY COMPETENCE THROUGH THE LENS OF CONFIDENCE IN PROBLEM SOLVING AND ATTITUDE TOWARDS MATHEMATICS"**.

The purpose of this letter is to provide you as the parent of a prospective thesis participant with information that may influence your decision to allow your child to participate in this thesis. The researchers will explain the study to you and answer all your questions. Before deciding whether or not to give your child permission to participate, read the information below and ask any questions you may have. This form will be used to record your permission if you decide to allow your child to participate in this study.

Purpose of the Study

If you agree, your child will be asked to participate in a research study about **"UNDERSTANDING STUDENTS' NUMERACY COMPETENCE THROUGH THE LENS OF CONFIDENCE IN PROBLEM SOLVING AND ATTITUDE TOWARDS MATHEMATICS"**. The purpose of this study is to check if the learner's learning style is a potential tool for the improvement of students' Numeracy Skills.

What is my child going to be asked to do?

If you allow your child to participate in this study, they will be asked to answer the questionnaire on their problem solving confidence, attitude towards mathematics, and answer the 1 to 40 item achievement tests after their math teacher discusses about certain topics. The target participants are the ninth-grade students at this school.

What are the risks involved in this study?

There are no foreseeable risks to participating in this study.

What are the possible benefits of this study?

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The possible benefits of this study are your child's knowledge of his confidence in problem solving to improve his academic performance in mathematics.

Does my child have to participate?

This research study will take place during regular classroom activities; however, if you do not want your child to participate, it will not affect their relationship of the school.

What if my child does not want to participate?

Your child must agree to participate in the study in addition to your permission. If your child declines to participate, he or she will not be included in the study and will face no consequences. If your child initially agrees to participate in the study, they can change their mind at any time without penalty.

Will there be any compensation?

Neither you nor your child will receive any type of payment participating in this study.

How will your child's privacy and confidentiality be protected if s/he participates in this research study?

The data collected as a result of your child's participation may be shared with other researchers in the

future for research purposes not specified in this consent form. In these cases, the data will be free of any identifying information that could be linked to your child or his or her participation in any study.

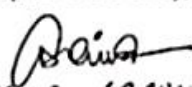
Whom to contact with questions about the study?

You can contact your child's Math teacher if you have questions about this study.

Whom to contact with questions concerning your rights as a research participant?

For questions about your rights or any dissatisfaction with any part of this study, you can contact the researchers by phone number 09499619004.

You are about to make a decision about whether or not to allow your child to participate in this study. By signing below, you acknowledge that you have read the information above and have decided to allow them to participate in the study. If you later decide that you wish to withdraw your child's permission to participate in the study, you may do so at any time. This document will be provided to you in its entirety


CONCHITA A. ARCHIVAL
Parent's Signature Over Printed Name

Thank you very much, God bless and more power! Respectfully yours,

Researcher

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Appendix B
PARENTAL CONSENT FOR CHILDREN PARTICIPATION

MRS. EPIFANIA M. REYES
BED Principal
St. Cecilia's College - Cebu, Inc.
Cebu South National Highway,
Ward II, Minglanilla, Cebu

Dear Madam:

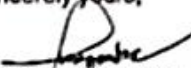
I am a graduate student of Cebu Technological University- Main Campus taking up Master of Arts in Education major in Mathematics. I am currently working on my thesis entitled **"UNDERSTANDING STUDENTS' NUMERACY COMPETENCE THROUGH THE LENS OF CONFIDENCE IN PROBLEM SOLVING AND ATTITUDE TOWARDS MATHEMATICS"** as one of the requirements of my course.

In line with this, I would like to ask permission from your good office to allow me to conduct data collection and administer the questionnaires to the Grade 9 students of your institution. Rest assured that the data collected in the research will be treated with utmost confidentiality and will only be used for the said purpose.

I am hoping for a favorable response on this matter.

Thank you and God Bless.

Sincerely yours,


ROSE S. GAMBOA
Researcher

Noted:


EMERSON D. PATEROS, Dev.Ed.D.
Adviser

Approved by:


MRS. EPIFANIA REYES
BED Principal

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Appendix C QUESTIONNAIRE FOR THE RESPONDENTS

Part I. Profile of the Respondents

Name: _____ Age: _____ Gender: _____ M _____ F

Directions: Put a checkmark (/) on your appropriate answer based on your profile.

Parents' Highest Educational Attainment:

Father

_____ Doctorate Graduate
 _____ With Doctorate Units
 _____ Master's Graduate
 _____ With Master's Units
 _____ College Graduate
 _____ College Level
 _____ High School Graduate
 _____ High School Level
 _____ Elementary Graduate
 _____ Elementary Level
 _____ No Formal Education

Mother

_____ Doctorate Graduate
 _____ With Doctorate Units
 _____ Master's Graduate
 _____ With Master's Units
 _____ College Graduate
 _____ College Level
 _____ High School Graduate
 _____ High School Level
 _____ Elementary Graduate
 _____ Elementary Level
 _____ No Formal Education

Combined Family Monthly Income:

_____ less than ₱10,957
 _____ between ₱10,957 - ₱21,914
 _____ between ₱21,915 - ₱43,828
 _____ between ₱43,829 - ₱76,699
 _____ ₱76,700 and above

Part II. Students' Attitudes Towards Mathematics

Directions: Read each statement carefully. Indicate how much you agree with each statement using the scale below.

- 1 – Strongly Disagree
- 2 – Disagree
- 3 – Neutral
- 4 – Agree
- 5 – Strongly Agree

A. Students' Attitudes Towards Mathematics as to Self-Confidence						
1.	Mathematics is a standout amongst my most feared subjects.					
2.	My mind goes blank, and I am unable to think clearly when working with math.					
3.	Studying mathematics makes me feel nervous.					
4.	Mathematics makes me feel uncomfortable.					

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5.	I am constantly under an awful strain in a math class.					
6.	When I hear the word mathematics, I feel uneasy.					
7.	It makes me nervous to even think about completing a math problem.					
8.	Mathematics does not scare me at all.					
9.	I expect to do well in any math class I take.					
10.	I am constantly confused in my math class.					
11.	I have a lot of self-confidence when it comes to mathematics.					
12.	I am able to solve math problems without much difficulty.					
13.	I feel insecure when trying to do mathematics.					
14.	I learn mathematics easily.					
15.	I believe that I am good at solving math problems.					
B. Students' Attitudes Towards Mathematics as to Value of Math						
1.	Mathematics is an essential and necessary subject.					
2.	I want to develop my mathematical skills.					
3.	Mathematics helps develop the mind and teaches us to think.					
4.	Mathematics is essential in everyday life.					
5.	Mathematics is one of the most important subjects for people to study.					
6.	High school math courses would be useful regardless of my career path.					
7.	I can think of many ways that I use math outside of school.					
8.	Studying advanced mathematics is useful.					
9.	Studying math helps me with problem-solving in other areas.					
10.	A solid math foundation could help me in my professional life.					
C. Students' Attitudes Towards Mathematics as to Enjoyment in Math						
1.	I get much satisfaction out of solving a math problem.					
2.	I have generally enjoyed studying math in school.					
3.	Mathematics is dull and boring.					
4.	I like to tackle new problems in mathematics.					
5.	I would rather complete a task in math than write an essay.					
6.	I like mathematics.					
7.	I am happier in a mathematics class than in any other class.					
8.	Mathematics is an interesting subject.					
9.	I am comfortable expressing my own ideas on how to solve a difficult math problem.					
10.	I am comfortable answering questions in math.					
D. Students' Attitudes Towards Mathematics as to Motivation in Math						
1.	I am confident that I could learn advanced mathematics.					
2.	I would like to avoid using mathematics in school.					
3.	I will take more than the required number of mathematics subjects.					
4.	I plan to take as much mathematics as I can during my education.					
5.	The challenge of mathematics appeals to me.					

Part III. Problem-Solving Confidence

Directions: Read each statement carefully. Indicate how much you agree with each statement using the scale below.

- 1 – Strongly Disagree
- 2 – Disagree
- 3 – Neutral
- 4 – Agree
- 5 – Strongly Agree

Problem-Solving Confidence		1	2	3	4	5
1.	I like to solve to a problem					
2.	I enjoy solving a problem					
3.	I like to solve a numeric problem					
4.	I do my best to be successful in problem solving					
5.	I am interested in problem solving					

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6. I like to struggle with solving problem even if I cannot solve the problem					
7. I like to solve problems from different sources					
8. I struggle with a problem until I find the correct answer					
9. I try too hard when I cannot solve the problem					
10. I am sure that I can solve a problem					
11. I am self confident in problem solving					
12. I am sure that I am able to solve even a difficult problem					
13. I do my best for solving the problem no matter how difficult a problem					
14. I lose track of time while solving a problem					
15. I demoralize if I cannot solve a problem					
16. I am stressed while solving a problem					
17. I lose self-confidence if I cannot solve a problem					
18. I am upset when I find incorrect answer of a problem					
19. I am afraid of making numerical mistakes					
20. Preconceptions prevent me from solving a problem					

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Part IV: Numeracy Test

Quarter: _____ Time: 60 minutes Total Items: 40

General Directions: Read each item carefully. Choose the letter of the correct answer and write it on your answer sheet. Avoid erasures.

- What is the product of $5x(x + 7)$?
A. $5x + 35$ B. $5x^2 + 7$ C. $5x^2 + 35x$ D. $x^2 + 35$
- Simplify $(x + 3)(x + 2)$.
A. $x^2 + 5x + 6$ B. $x^2 + 6x + 5$ C. $x^2 + 5x + 2$ D. $x^2 + 4x + 3$
- Find $(x - 4)^2$.
A. $x^2 + 8x + 16$ B. $x^2 - 8x + 16$ C. $x^2 - 16x + 4$ D. $x^2 + 16$
- Simplify $(t + 2)^2$.
A. $t^2 + 4t + 4$ B. $t^2 + 2t + 2$ C. $t^2 + 4$ D. $t^2 + 2t + 4$
- Multiply $(8 + r)(r - 5)$.
A. $r^2 - 5r + 8$ B. $r^2 + 3r - 40$ C. $r^2 + 8r - 5$ D. $r^2 + 8r + 5$
- Simplify $3(x + 4)$.
A. $3x + 12$ B. $x + 12$ C. $12x + 3$ D. $3x + 4$
- Find the value of x in $x + 8 = 15$.
A. 7 B. 8 C. 9 D. 6
- Evaluate $2(x + 3) - x$ when $x = 4$.
A. 10 B. 8 C. 5 D. 2
- Solve $3(x + 2) = 12$.
A. 2 B. 3 C. 4 D. 5
- Solve $-5 = 4 + x$.
A. 1 B. -1 C. -9 D. 9
- Find x if $7 - x = 2x - 14$.
A. 3 B. 7 C. 9 D. 14
- Solve $2x = 4 - 12$.
A. 4 B. -4 C. 8 D. -8
- Find the solution of $7(3x - 4) = 14$.
A. $x = 10/3$ B. $x = 2$ C. $x = 4$ D. $x = 3$
- Simplify $4(x - 2) + 8 = 0$.
A. $x = 2$ B. $x = -2$ C. $x = 0$ D. $x = 4$
- Solve the unknown value of $(2s - 1)^2 = 225$
A. 8 B. 9 C. 10 D. 11
- Solve the unknown value of $(k + 7)^2 = 289$
A. 10 B. 14 C. -7 D. 17
- Find the positive root of $x^2 = 16$
A. 4 and -4 B. 8 C. 2 and -2 D. 16

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18. Find the roots of the given equation, $3h^2 - 147 = 0$
A. ± 7 B. ± 9 C. ± 10 D. ± 14
19. Find the roots of the given equation, $2s^2 = 50$
A. ± 4 B. ± 5 C. ± 6 D. ± 7
20. Find the roots of the given equation, $x^2 + 9x + 8 = 0$
A. -1, -8 B. -8, -1 C. -8, -9 D. 8, 1
21. Find the positive root of $t^2 + 8t + 16 = 0$
A. -4 B. -8 C. 4 D. 8
22. Find the positive root of $4s^2 - 12s + 9 = 0$
A. $3/2$ B. 3 C. 1 D. -3
23. Find the roots of the given equation, $x^2 - 5x - 14 = 0$
A. 7, -2 B. -7, 2 C. 5, 9 D. 2, -5
24. $x^2 - 10x + 25 = 0$
A. 10 B. 5 C. -5 D. -10
25. Find the roots of the given equation, $x^2 - 14 = 5$
A. 2, 7 B. 7, 2 C. 7, -2 D. -7, -2
26. Find the roots of the given equation, $2x^2 + 8x - 10 = 0$
A. -5, 1 B. 1, 5 C. -1, 5 D. -5, -1
27. Find the roots of the given equation, $s^2 + 4s - 21 = 0$
A. 3, -7 B. -3, 7 C. -7, -3 D. 7, 3
28. Find the roots of the given equation, $2x^2 + 3x = 27$
A. 3, -4.5 B. -3, 4.5 C. 9, -3 D. -9, 3
29. Find the roots of the given equation, $2x^2 + 7x + 9 = 0$
A. No real roots B. -1, -9 C. 1, -9 D. 9, -1
30. Find the roots of the given equation, $3x^2 - 12x + 12 = 0$
A. No real roots B. -2, -2 C. 2, -2 D. 2, 2
31. Transform $x(x + 5) = 2$ into standard quadratic form.
A. $x^2 + 5x - 2 = 0$ B. $x^2 + 5x + 2 = 0$
C. $x^2 - 5x - 2 = 0$ D. $x^2 + 2x + 5 = 0$
32. Expand $(s + 6)^2 = 5$.
A. $s^2 + 12s + 36 = 5$ B. $s^2 + 6s + 5 = 0$
C. $s^2 + 12s + 31 = 0$ D. $s^2 + 12s + 36 = 0$
33. $(2r + 3)^2 + (r + 4)^2 = 10$ simplifies to
A. $5r^2 + 20r + 25 = 0$ B. $5r^2 + 16r + 25 = 0$
C. $5r^2 + 12r + 25 = 0$ D. $5r^2 + 14r + 25 = 0$
34. $(m - 4)^2 + (m - 7)^2 = 15$
A. $2m^2 - 22m + 65 = 0$ B. $2m^2 - 18m + 50 = 0$
C. $2m^2 - 14m + 45 = 0$ D. $2m^2 - 22m - 65 = 0$
35. If y varies directly as x and y = 24 when x = 6, find the constant of variation.
A. 3 B. 4 C. 6 D. 2

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36. If x varies directly as y and x = 35 when y = 7, find y when x = 25.
A. 3 B. 4 C. 5 D. 6
37. If y varies inversely as x and y = 5 when x = 2, find y when x = 4.
A. 10 B. 4 C. 2.5 D. 20
38. A rectangle's area is $A = lw$. If $A = 48$ and $l = 8$, find w.
A. 5 B. 6 C. 7 D. 8
39. The average of 5 numbers is 20. If one number is 10, what is the average of the remaining 4?
A. 18 B. 20 C. 22.5 D. 25
40. A number is increased by 8, then multiplied by 3. The result is 36. What is the number?
A. 2 B. 4 C. 6 D. 8

Appendix D Statistical Report

Profile of the respondents

Count		age * gender Crosstabulation		
		gender		Total
		F	M	
age	14	39	30	69
	15	11	15	26
	16 and above	3	2	5
Total		53	47	100

		father			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-DOCTORATE GRADUATE	2	2.0	2.0	2.0
	2-MASTER'S GRADUATE	4	4.0	4.0	6.0
	3-WITH MASTERS UNITS	2	2.0	2.0	8.0
	4-COLLEGE GRADUATE	58	58.0	58.0	66.0
	5-COLLEGE LEVEL	12	12.0	12.0	78.0
	6-HIGH SCHOOL GRADUATE	12	12.0	12.0	90.0
	7-HIGH SCHOOL LEVEL	7	7.0	7.0	97.0
	8-ELEMENTARY LEVEL	2	2.0	2.0	99.0
	9-NO FORMAL EDUCATION	1	1.0	1.0	100.0
	Total	100	100.0	100.0	

		mother			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-DOCTORATE GRADUA	2	2.0	2.0	2.0
	1-WITH DOCTORATE U	1	1.0	1.0	3.0
	2-MASTER'S GRADUAT	1	1.0	1.0	4.0
	3-WITH MASTERS UNI	4	4.0	4.0	8.0
	4-COLLEGE GRADUATE	68	68.0	68.0	76.0

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	GIF (Australia)	= 0.564	ESJI (KZ)	= 8.100	IBI (India)	= 4.260
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5-COLLEGE LEVEL	9	9.0	9.0	85.0
6-HIGH SCHOOL GRAD	14	14.0	14.0	99.0
7-HIGH SCHOOL LEVE	1	1.0	1.0	100.0
Total	100	100.0	100.0	

income				
	Frequency	Percent	Valid Percent	Cumulative Percent
Valid 1-76700 AND ABOVE	15	15.0	15.0	15.0
2-BET 43829-76699	18	18.0	18.0	33.0
3-BET 21915-43828	32	32.0	32.0	65.0
4-BET 10957-21914	22	22.0	22.0	87.0
5-LESS 10957	13	13.0	13.0	100.0
Total	100	100.0	100.0	

Level of respondents attitudes towards Mathematics
Self-confidence

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
S1	100	1.00	5.00	3.3800	1.02277
S2	100	1.00	5.00	3.1000	1.05887
S3	100	1.00	5.00	2.7700	1.17082
S4	100	1.00	5.00	2.3600	1.11482
S5	100	1.00	5.00	2.7100	1.07586
S6	100	1.00	5.00	2.3100	1.18658
S7	100	1.00	5.00	2.7300	1.34731
S8	100	1.00	5.00	2.7200	1.10170
S9	100	1.00	5.00	3.0200	1.07290
S10	100	1.00	5.00	2.9600	1.09101
S11	100	1.00	5.00	2.6200	1.07101
S12	100	1.00	5.00	2.7300	1.21319
S13	100	1.00	5.00	3.0000	1.23091
S14	100	1.00	5.00	2.8200	1.04813
S15	100	1.00	5.00	2.7800	1.09710
Valid N (listwise)	100				

Value

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
V1	100	1.00	5.00	4.1200	1.07572
V2	100	2.00	5.00	4.5400	.80929
V3	100	2.00	5.00	4.1900	.82505
V4	100	1.00	5.00	3.8800	1.05677
V5	100	2.00	5.00	4.1000	.85870
V6	100	2.00	5.00	4.0100	.96917
V7	100	1.00	5.00	3.6100	1.09078
V8	100	1.00	5.00	4.0600	.97255
V9	100	2.00	5.00	3.9300	.91293
V10	100	1.00	5.00	4.0000	.93203
Valid N (listwise)	100				

Enjoyment

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation

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	GIF (Australia)	= 0.564	ESJI (KZ)	= 8.100	IBI (India)	= 4.260
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E1	100	1.00	5.00	3.6000	1.23091
E2	100	1.00	5.00	3.1400	.96421
E3	100	1.00	4.00	2.1100	.88643
E4	100	1.00	5.00	2.8800	1.02770
E5	100	1.00	5.00	2.8000	1.44250
E6	100	1.00	5.00	3.1300	1.13400
E7	100	1.00	5.00	2.6800	1.08134
E8	100	2.00	5.00	3.8100	.91778
E9	100	1.00	5.00	2.7400	1.02119
E10	100	1.00	5.00	2.9200	.92856
Valid N (listwise)	100				

Motivation

	N	Descriptive Statistics		Mean	Std. Deviation
		Minimum	Maximum		
M1	100	1.00	5.00	2.8500	1.15798
M2	100	1.00	5.00	2.2800	.99575
M3	100	1.00	5.00	2.5000	.84686
M4	100	1.00	5.00	3.0100	.96917
M5	100	1.00	5.00	3.2200	.93830
Valid N (listwise)	100				

Level of problem-solving confidence of the respondents

	N	Descriptive Statistics		Mean	Std. Deviation
		Minimum	Maximum		
VAR00022	100	1.00	5.00	3.1000	1.05887
VAR00023	100	1.00	5.00	3.1000	1.06837
VAR00024	100	1.00	5.00	2.9600	1.01424
VAR00025	100	1.00	5.00	3.9000	.87039
VAR00026	100	1.00	5.00	3.2800	.97525
VAR00027	100	1.00	5.00	3.1400	1.16359
VAR00028	100	1.00	5.00	3.0000	1.00504
VAR00029	100	1.00	5.00	3.7000	.85870
VAR00030	100	1.00	5.00	3.6000	1.06363
VAR00031	100	1.00	5.00	2.8400	1.12564
VAR00032	100	1.00	5.00	2.8100	1.07961
VAR00033	100	1.00	5.00	2.5700	1.12146
VAR00034	100	2.00	5.00	3.7900	.87957
VAR00035	100	1.00	5.00	3.5800	1.13867
VAR00036	100	1.00	5.00	2.9700	1.02942
VAR00037	100	1.00	5.00	3.3800	1.08971
VAR00038	100	1.00	5.00	3.3500	1.39534
VAR00039	100	1.00	5.00	3.4200	1.26475
VAR00040	100	1.00	5.00	3.6700	1.09226
VAR00041	100	1.00	5.00	2.9200	.84900
Valid N (listwise)	100				

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Level of numeracy skills of the respondents

		VAR00043			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-33-40	3	3.0	3.0	3.0
	2-25-32	11	11.0	11.0	14.0
	3-17-24	48	48.0	48.0	62.0
	4-9-16	35	35.0	35.0	97.0
	5-0-8	3	3.0	3.0	100.0
	Total	100	100.0	100.0	

Test of Normality of the variables

Descriptives			
	attitudes	problem solving	numeracy test scores
N	100	100	100
Missing	0	0	0
Mean	3.15	3.25	18.4
Median	3.14	3.25	18.0
Standard deviation	0.341	0.510	5.67
Minimum	2.20	1.65	6
Maximum	3.95	4.45	35
Shapiro-Wilk W	0.980	0.954	0.958
Shapiro-Wilk p	0.138	0.002	0.003

Test of the hypotheses

Correlation Matrix				
		attitudes	problem solving	numeracy test scores
attitudes	Spearman's rho	—		
	df	—		
	p-value	—		
problem solving	Spearman's rho	0.609***	—	
	df	98	—	
	p-value	<.001	—	
numeracy test scores	Spearman's rho	0.168	0.202*	—
	df	98	98	—
	p-value	0.094	0.044	—

Note. * p < .05, ** p < .01, *** p < .001

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	JIF	= 1.500	SJIF (Morocco)	= 6.004	OAJI (USA)	= 0.350

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Passed

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ANALYSIS OF THE TEMPERATURE AND THERMAL STRESS STATE OF MARINE ENGINE COMPONENTS

Abstract: Maintaining the temperature and thermal stress of engine components within permissible limits is impossible without some heat loss. It has been established that only 35–45% of the thermal energy is converted into useful (effective) energy. To determine the thermal stress experienced by individual components, the heat released in the cylinder must be apportioned among them. The engine's thermal balance makes it possible to assess the degree of heat utilization, quantify heat losses, and evaluate the potential for reducing them. In turn, the degree of heat utilization can be improved through the recovery of waste heat.

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The thermal stress of engine components is determined not only by the magnitude of the thermal balance components, but also by the heat flux density and intensity. The bottom of the cylinder heads and the piston crown are characterized by the highest heat flux densities. The result of the thermal stress magnitude is the mechanical properties of materials, which determines the reliability and durability of components and assemblies. The thermal stress of engine components can be assessed using various criteria.

Key words: heat flux density and intensity; thermal stress; useful energy; heat utilization efficiency; heat losses; thermal energy recovery; mechanical properties of materials; reliability and durability of components.

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Introduction

The work process in internal combustion engines involves the release of a large amount of heat in the engine cylinder due to fuel combustion, which causes periodic increases in the temperature of the cylinder and piston group components. Under high-pressure, sealed conditions, contact between hot gases and the combustion chamber, cylinder head, cylinder, and piston surfaces causes overheating, which can lead to oil burning, increased friction, component failure, and other issues. Reliable and long-term operation of engine mechanisms is only possible under strictly defined thermal conditions. Overheating causes the thermal expansion of components, leading to deterioration or complete seizure of moving parts. It also reduces cylinder filling, causes oil coking, and can lead to the failure of the valve plate, cylinder head, and other components. In the case of excessive cooling, mixture formation deteriorates, thermal and mechanical losses increase, and wear intensifies.

To avoid these problems and ensure normal engine operation, it is necessary to select a cooling system that maintains the optimum temperature of the engine components within the optimal operating range.

The heat transfer process occurring in the cylinder of an internal combustion engine is a highly complex physical phenomenon, as it involves radiation, conduction, and convection simultaneously [1,2]. At the initial stage, during the ignition and combustion of the fuel-air mixture, radiant energy is transferred to the walls of the combustion chamber and the cylinder head.

At the next stage, convective heat transfer occurs between the coolant and the walls of the cooling jacket. The intensity of this process depends on both structural parameters and the properties of the cooling medium. In other words, the intensity of convective heat transfer is determined by the flow dynamics and the microstructure of the moving medium [3].

As Purtskhvanidze, G., Lejava, M., Shubladze, Z., Gvetadze, V., & Zoidze, V. (2026) [4] noted that „from an energy perspective, heat transfer under nuclear boiling conditions is more favorable because the high heat transfer coefficient allows for efficient

heat removal from cooled surfaces at low coolant flow rates“.

The reliability of marine engine operation is affected by the water-chemical parameters in the engine cooling system when various chemical additives are used. This is presented in the paper Purtskhvanidze, G., Lejava, M., Shubladze, Z., Kamladze, A., & Kiknadze, M. (2026) [5], “During the research, it was noted that when additives are used, the enhancement of the anti-corrosion protective effect is associated with an increase in fluid temperature, which is an important factor in maintaining the protective properties of the additives in high-temperature cooling systems.”

Basic part: The thermal energy released during fuel combustion in the engine cylinder cannot be fully converted into useful work because it is impossible to maintain the temperature and thermal stresses of the engine components within permissible limits without dissipating a portion of the generated heat. In modern transport internal combustion engines, depending on their design, type, and quality of the work process, 35–50% of the released thermal energy is converted into effective work, while the rest is distributed among various types of losses.

To determine the thermal and temperature stresses of engine components, it is necessary to know how the heat released in the engine cylinder is distributed among its various components. This distribution is referred to as the external heat balance.

The external heat balance allows us to assess the extent of heat utilization, quantify thermal losses, and evaluate the potential for reducing them. It identifies effective ways to utilize the energy of the exhaust gases, design the main elements of the cooling system, and improve engine performance. It should be noted that changes in the engine’s speed and load characteristics significantly affect the components of the heat balance. Therefore, for marine engines, the heat balance equation is derived with external speed for load and propeller characteristics. The heat balance equation is drawn up in absolute units per 1 kg or 1 m³ of fuel consumed during 1 hour of engine operation. The heat balance equation for the external

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speed characteristic of a combined engine, expressed in absolute units, is written as follows:

$$Q = Q_e + Q_{e.s.} + Q_{e.g.} + Q_{lubr.} + Q_{s.h.}, \quad (1)$$

where Q - is the total amount of heat released as a result of fuel combustion in the engine cylinder.

$$Q = G_{c.h} + H_u \quad (2)$$

where $G_{c.h}$ - is the amount of fuel consumed by the engine in 1 hour, and H_u - is the lowest heat of combustion of the fuel.

$Q_e = 632 \text{ Ne kcal/hr}$ - is the heat equivalent of the work performed by the engine.

$Q_{e.s.}$ - is the amount of heat transferred to the cooling agent by the engine. If we determine the amount of coolant G_c passing through the cooling jackets per unit time and measure the temperatures at the inlet and outlet of the system, then the amount of heat transferred to the cooling system is as follows:

$$Q_{e.s.} = G_i \cdot c(t_i - t_o), \quad (3)$$

where c - is the specific heat capacity of the cooling agent.

$Q_{e.g.}$ - is the amount of heat carried away by the exhaust gases leaving the cylinder, and it can be written that

$$Q_{e.g.} = Q_{e.g.ent.} + Q_{inc.com.} \quad (4)$$

where $Q_{e.g.ent.}$ - is the enthalpy of the exhaust gases, and $Q_{inc.com.}$ - is the thermal energy lost due to the incomplete combustion of heat.

$Q_{lubr.}$ - is the amount of heat removed by the oil during the lubrication process;

$Q_{s.h.}$ - heat spent on the operation of various auxiliary mechanisms of the engine.

In most cases, the heat balance equation is written using relative quantities, where each component is expressed as a percentage.

$$q_e + q_{e.s.} + q_{e.g.} + q_{inc.com.} + q_o + q_{s.h.} = 100\% \quad (5)$$

Table 1 presents the average values of the individual components of the external heat balance of a diesel engine during operation at nominal operation of the engine.

Table 1 - Values of the components of the external heat balance of various types of engines

Type of engine	q_e	$q_{e.s.}$	$q_{e.g.}$	$q_{inc.com.}$	q_o	$q_{s.h.}$
Aspirate diesel engine	29-42	20-35	25-40	0-5	2-4	2-7
Supercharged engine	40-48	10-18	20-40	0-7	4-8	2-5

As shown in Table 1, 52–78% of the thermal energy released in the engine is accounted for by heat losses, primarily via the exhaust gases and the cooling system.

The degree of heat utilization can be increased by recovering heat losses. For example, on high-

power vessels, the heat from exhaust gases is used in waste-heat recovery boilers. In recent years, on low-power vessels, exhaust gas heat has been utilized in thermochemical generators. In combined marine engines, 10–18% of the heat is removed by the cooling system.

Table 2 - Heat balance components during operation of a river vessel's diesel engine on propeller characteristics

Heat balance components	Loads, %			
	25	50	75	100
Equivalent heat for effective engine operation	25,7	30,5	33,6	35,4
Heat carried away by exhaust gases	24,8	26,2	27,0	25,0
Heat transferred to the coolant	41,3	34,8	31,9	33,5
Uncounted heat losses	8,2	8,5	7,5	6,1

The table shows that, at nominal operating conditions, heat losses on the cooling water are approximately equal to the heat used to perform useful work, whereas at loads below 75%, the heat transferred to the cooling water exceeds the useful heat output.

Figure 1 illustrates a heat distribution graph showing the variation of the balance components during engine operation under different load conditions.

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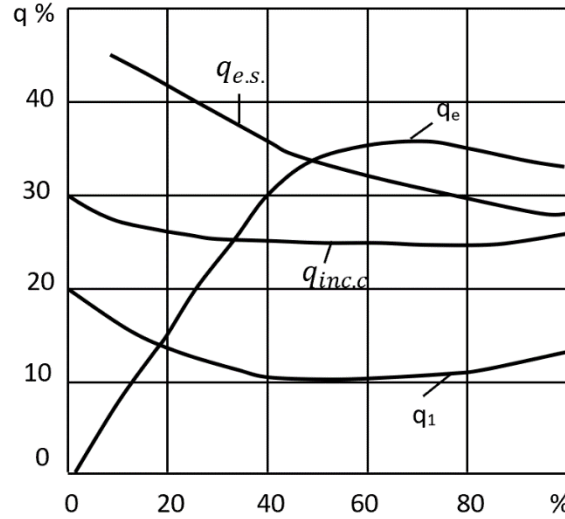


Fig. 1. Variation of external heat balance components depending on engine loads

The temperature and thermal stress state of engine components are determined not only by the magnitude of the thermal balance components, but also by the heat flux density and intensity. As a rule, the main heat-receiving surfaces are the bottom of the cylinder heads, the cylinder liner mirrors, and the piston crown. At the same time, the distribution of heat flux from the working medium in the cylinder to individual elements is significantly non-uniform. Moreover, the underside of the cylinder head and the piston crown exhibit the highest heat flux density.

Thermal stress in components refers to the temperatures of the main components, which are characterized by absolute temperature values and temperature gradients. Their magnitude results in the mechanical properties of materials, temperature stresses, lubrication conditions of friction surfaces, and other factors that directly determine the reliability and durability of components and assemblies.

The concept of thermal stress refers to the amount of heat removed from the unit heat-receiving surface by the cooling system per unit time.

$$\Delta t = t_{max} - t_{min} \quad (6)$$

In turbocharged engines, the following formula is recommended for assessing the thermal stress of the piston-cylinder group components:

$$q_n = b \cdot C_m^{0.5} \cdot \left(1.36 \frac{T_{inc}}{T_0}\right)^{0.38} \cdot \left(\frac{d}{\eta_v \cdot P_{inl}}\right)^{0.38} \quad (7)$$

where b - is the proportionality coefficient, for four-stroke engines, $b = 1$;

P_{inl} - cylinder filling pressure, MPa;

T_{inc} - temperature of air entering the cylinder, K;

d - Cylinder diameter, dm;

η_v - coefficient of admission;

T_0 - air temperature under normal conditions.

Using the thermal stress factor q_n , the service life can be determined by the following relationship:

$$T = \frac{U_l}{v} = \frac{u_l}{60 q_n p_z \cdot k' \cdot n} \quad (8)$$

where U_l - limiting wear, determining the service life of components;

k' - coefficient that takes into account the design features of the engine;

n - engine crankshaft rotation frequency, min^{-1} ;

p_z - maximum cycle pressure, MPa;

q_n - thermal stress factor.

If we assume that the limiting wear of components is proportional to the diameter of the engine cylinder, then

$$T = k' \cdot \frac{d \cdot 10^3}{q_n p_z \cdot n} \quad (9)$$

The thermal stress of the cylinder and piston group components can be assessed using various criteria. For example, the thermal stress developed on the piston crown can be determined by the amount of heat transferred to the cooling agent and expressed by the formula:

$$Q_p = v N_e g_e \cdot H_u \quad (10)$$

where N_e - effective power per cylinder;

g_e - effective specific fuel consumption;

H_u - lowest calorific power of fuel;

v - the portion of total heat removed by the piston crown, with oil cooling $v = 0.04 - 0.06$, with water cooling $v = 0.06 - 0.09$.

In recent years, the finite element method and the control volume method have been widely used to determine the local temperature of components and their thermal stress state [6]. In this case, the amount of heat transferred during the cycle to a surface with an area ΔF is determined by the formula [7]:

$$Q = \Delta F \cdot \int_0^{t_0} \alpha (T - T_w) dt \quad (11)$$

while in the equivalent steady-state mode:

$$Q = t_0 \alpha (T_{eq}) \Delta F \quad (12)$$

where α - is the average equivalent coefficient of heat transfer.

T_{eq} and T_w - the average equivalent temperatures of the gas and the wall.

From equations (1.11) and (1.12), we obtain the equivalent heat transfer parameters for the steady-state mode

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$$\alpha (T_{eq} - T_w)t_0 = \int_0^{t_0} \alpha (T - T_w)dt \quad (13)$$

If we assume that $T_{eq} = T_w$, we obtain a simplified formula for determining the equivalent heat transfer parameters:

$$\alpha_{eq} = \alpha_{av} = \frac{1}{t_0} \int_0^{t_0} \alpha dt \quad (14)$$

from which

$$T_{eq} = \frac{(\alpha T)_{av}}{\alpha_{av}}. \quad (15)$$

Every component, based on its design properties and operating conditions, has a maximum permissible temperature. For example, for components made of aluminum alloys, the maximum temperature should not exceed 250-300°C; for cast iron components, this value is 400-450°C, and for alloyed steels – 450-500°C. [7].

Table 3 presents the limiting temperatures for the components of the piston-cylinder group made of various materials.

Table 3 - The limiting temperatures for the components of the piston-cylinder group

Piston crown temperature	Light-metal alloy Al-1	2000-250 °C
	Light-metal alloy Al-4	300-350 °C
	Steel	400-475 °C
	Cast iron	400-250 °C
Temperature in the zone of the No 1 ring of the piston		200-210 °C
Cylinder face temperature in the head-land ring		200 °C

Exceeding these temperatures leads to changes in the metal structure and deterioration of its physical properties, resulting in an immediate reduction in component reliability. In this regard, some countries have conducted research into thermal insulation of relatively heated components, which causes changes in the thermal state of engine components [8, 9]. It should also be noted that, in some cases, thermal insulation of the combustion chamber has resulted in reduced engine efficiency due to changes in the working process and increased heat losses. This phenomenon results from changes in mixture formation, ignition, and combustion processes, as well as an increase in the radiative component of heat transfer within the cylinder. Consequently, the use of ceramic materials is not considered acceptable in either modern or future marine diesel engines, which are required to ensure high efficiency and long service life.

Thus, only a liquid cooling system can ensure reliable operation of a marine engine over a long

period. Under conditions of maximum working-cycle temperatures, which in modern diesel engines range from 1700–2700°C [10], the cooling system design and its individual components must ensure reliable heat transfer and minimal energy consumption for circulating the coolant.

Conclusions

Based on the research and analysis conducted, the following conclusions can be drawn:

- The thermal balance of the engine allows assessment of the degree of heat utilization, heat losses, and potential ways to reduce them;
- The degree of heat utilization can be increased by recovering heat losses;
- At engine loads below 75%, the heat transferred to the cooling water exceeds the useful heat output, whereas at nominal load conditions, they are approximately equal.

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MODELING AND ANALYSIS OF THE SHEET METAL DRAWING PROCESS TAKING INTO ACCOUNT NORMAL AND SHEAR STRESSES

Abstract: During the drawing process, the metal sheet is subjected to various types of deformation. To evaluate the stress and strain state of the material after drawing under the same conditions, several grades of steel, a deformable aluminum alloy, and commercially pure titanium were considered. The description of shear deformations and tensile and compressive deformations of the materials under consideration was carried out using the calculated maximum values of shear stress along three coordinate planes and normal stress along three coordinate axes.

Key words: metal sheet, drawing, normal stress, shear stress.

Language: English

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1. Introduction

The sheet metal drawing process is a key step in the production of complex metal parts and requires careful consideration of both normal and shear

stresses occurring in the material. Despite significant progress, challenges remain in managing residual stress distribution and preventing defects such as thinning and excessive deformation.

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In recent years, research in the field of deep drawing has focused on modeling and experimental analysis methods, as evidenced by the work of El-Garf et al. [1], who conducted a comprehensive study using simulations and experiments to understand the formation process of cylindrical cups. Hartmann and Volk [2] and Serebrennikova et al. [8] study the forming of hybrid parts, emphasizing the influence of process parameters on product quality. An important aspect is the analysis of residual stresses and their influence on the properties of materials, which is investigated in the works of Zein et al. [3], Danckert [4], and in the latest publications of Zaława and Medei et al. [5-7]. Modern methods, including the use of artificial neural networks for stress prediction, show promise for improving modeling accuracy [9-10].

The aim of this study is to apply computer modeling for a comprehensive analysis of the drawing process of thin-walled housing parts, taking into account normal and shear stresses in the deformed material, which will optimize the technological process and improve the quality of final products made of steel, deformable aluminum alloy and commercially pure titanium.

2. Materials and methods

To calculate the stress state of a three-dimensional model of sheet metal with a thickness of 0.8 mm, the LS-DYNA special program was used. The process of modeling the drawing of a square metal sheet was carried out to a depth of 20 mm. Since the object of study was a sheet metal model, the remaining models of the drawing die (punch, die and blankholder) were created as absolutely rigid bodies.

In this case, the accuracy of the modeling results was achieved by assigning to the sheet models the Lankford coefficients, strain hardening exponents, physical and mechanical properties of DC01 structural high-quality carbon steel, DC05 high-quality cold-rolled low-carbon steel, AISI 304 austenitic stainless steel, S355MC high-strength low-alloy steel, 5754 deformable aluminum alloy, and Ti Grade 4 commercially pure titanium.

The calculated values of the stress state of each model after drawing were taken from the parameters of x -stress, y -stress and z -stress, which characterize the normal stresses arising in the material along the corresponding coordinate axes and from the parameters of xy -stress, yz -stress and zx -stress, which characterize the shear stresses arising in the material along the corresponding coordinate planes.

3. Results and discussion

Figure 1 shows the deformed geometry of a square metal sheet model after a drawing process to a depth of 20 mm. The model reflects characteristic changes in shape, which is important for assessing the manufacturability and reliability of processing.

Table 1 shows the calculated values of normal stresses (σ) and shear stresses (τ) for various grades of steel, deformable aluminum alloy and commercially pure titanium along three coordinate axes and planes, respectively. Negative normal stress values indicate compression regions, while positive values indicate tension regions. Shear stresses with a positive sign are oriented along the positive direction of the coordinate axis on the face with a positive normal, and negative ones are oriented in the opposite direction.

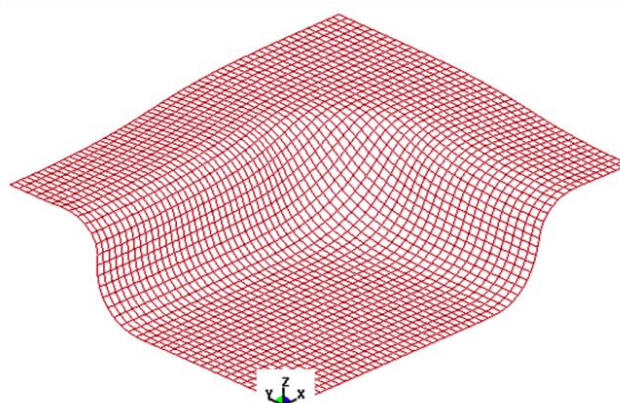


Figure 1. Model of metal sheet after drawing.

Table 1. Calculated values of normal and shear stresses in the material of the part along the coordinate axes of X , Y , Z and coordinate planes of XY , YZ , ZX .

DC01 structural high-quality carbon steel		
σ_x , MPa	-409.981	446.834
σ_y , MPa	-461.286	445.416
σ_z , MPa	-32.517	350.354

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τ_{xy} , MPa	-108.263	316.76
τ_{yz} , MPa	-47.1775	231.404
τ_{zx} , MPa	-61.5755	219.193
DC05 high-quality cold-rolled low-carbon steel		
σ_{x_3} , MPa	-365.508	455.794
σ_{y_3} , MPa	-419.436	456.5
σ_{z_3} , MPa	-51.216	349.127
τ_{xy_3} , MPa	-87.4779	302.985
τ_{yz_3} , MPa	-50.7705	234.896
τ_{zx_3} , MPa	-53.0267	224.666
S355MC high-strength low-alloy steel		
σ_{x_3} , MPa	-523.616	1172.81
σ_{y_3} , MPa	-522.54	1331.52
σ_{z_3} , MPa	-231.783	826.302
τ_{xy_3} , MPa	-203.332	386.024
τ_{yz_3} , MPa	-238.873	731.7
τ_{zx_3} , MPa	-197.838	539.682
AISI 304 austenitic stainless steel		
σ_{x_3} , MPa	-425.68	420.822
σ_{y_3} , MPa	-478.401	425.885
σ_{z_3} , MPa	-26.136	327.19
τ_{xy_3} , MPa	-118.053	321.791
τ_{yz_3} , MPa	-34.8687	216.723
τ_{zx_3} , MPa	-53.851	203.703
5754 deformable aluminum alloy		
σ_{x_3} , MPa	-164.6	210.079
σ_{y_3} , MPa	-187.918	213.868
σ_{z_3} , MPa	-18.7518	223.423
τ_{xy_3} , MPa	-57.2409	145.954
τ_{yz_3} , MPa	-37.7327	122.015
τ_{zx_3} , MPa	-33.0665	117.408
Ti Grade 4 commercially pure titanium		
σ_{x_3} , MPa	-658.116	1289.89
σ_{y_3} , MPa	-694.225	1165.49
σ_{z_3} , MPa	-47.2773	1320.11
τ_{xy_3} , MPa	-199.486	597.837
τ_{yz_3} , MPa	-218.952	593.169
τ_{zx_3} , MPa	-217.1	588.064

Data analysis shows that all materials exhibit significant stress states, with maximum normal and shear stress values occurring on the X and Y axes. Particularly high stresses are characteristic of S355MC high-strength low-alloy steel and Ti Grade 4 commercially pure titanium, indicating their high strength and simultaneous difficulty in deformation. At the same time, the 5754 deformable aluminum alloy exhibits the lowest stress values, which is associated with its higher ductility and lower strength.

This stress distribution indicates non-uniform deformation in the drawing zone: the central sections experience tension, while the peripheral sections experience compression. High shear stresses indicate the presence of significant shear deformations, which is important to consider when designing a process to prevent cracks and surface defects in the housing part.

4. Conclusion

During the study, a detailed calculation of the stress and strain state was carried out for various grades of steel, deformable aluminum alloy, and commercially pure titanium, which made it possible to obtain quantitative values of normal and shear stresses. The highest values of normal stresses along the X and Y axes were recorded for Ti Grade 4 commercially pure titanium – up to 1289.89 MPa and 1165.49 MPa, respectively, as well as for S355MC high-strength low-alloy steel with maximum values of up to 1172.81 MPa and 1331.52 MPa. The shear stresses of τ_{xy} , τ_{yz} and τ_{zx} also reached maximum values for these materials, which indicates their high strength and ability to withstand complex loads.

DC01 and DC05 steels, as well as AISI 304 austenitic stainless steel, showed moderate stress values, making them optimal for structures requiring

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strength and ductility. In contrast, the 5754 deformable aluminum alloy is characterized by significantly lower stress values, which corresponds to its use in lightweight structures and products with low weight requirements.

The practical value of the results lies in the possibility of using the obtained calculation data to

optimize the design and selection of materials depending on operating conditions and strength requirements. These stress values can serve as a basis for further analysis of the fatigue strength and durability of products, as well as for the development of effective technological processes for processing and strengthening materials.

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HYDROCHEMICAL INVESTIGATION OF BIOLOGICALLY ACTIVE IONS IN THE SPRING WATERS OF SUJUNA VILLAGE, ABASHA MUNICIPALITY, SAMEGRELO–ZEMO SVANETI REGION, GEORGIA

Abstract: The present study investigates the hydrochemical composition of spring waters located in Sujuna Village, Abasha Municipality, Samegrelo–Zemo Svaneti Region, Georgia. The research aimed to determine the

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concentrations of biologically active and environmentally significant physicochemical parameters, including pH, total hardness, magnesium (Mg^{2+}), calcium (Ca^{2+}), total iron, copper (Cu^{2+}), chloride (Cl^-), bromide (Br^-), bicarbonate (HCO_3^-), sulfate (SO_4^{2-}), total arsenic, permanganate oxidizability, dissolved oxygen (DO), biochemical oxygen demand (BOD_5), and free carbon dioxide (CO_2). Water samples collected from three natural springs were analyzed using standard hydrochemical and photometric methods at the Iason Moseshvili Hydrochemical Laboratory, Department of Chemistry, Faculty of Exact and Natural Sciences, Akaki Tsereteli State University. The obtained results revealed slight variations in the concentrations of the investigated parameters among the studied springs. Most measured values complied with the requirements of the Georgian Technical Regulation for Drinking Water, indicating satisfactory water quality for drinking and domestic use. A slight exceedance of the recommended concentration of total arsenic was observed in the investigated springs, suggesting the need for continuous environmental monitoring. The findings provide valuable baseline information on the hydrochemical characteristics of spring waters in the study area and contribute to the assessment and sustainable management of local groundwater resources.

Key words: spring water, hydrochemical analysis, biologically active ions, groundwater quality, drinking water, Sujuna Village, Abasha Municipality, Georgia.

Language: English

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Introduction

Water is one of the most essential natural resources and plays a fundamental role in sustaining human life, ecosystems, and economic development. It is indispensable for domestic consumption, agriculture, industry, energy production, transportation, and environmental protection. The availability of high-quality freshwater resources is therefore of great importance for public health and sustainable regional development.

Spring waters represent naturally discharged groundwater that has undergone natural filtration through geological formations. Owing to this process, spring water is generally characterized by relatively stable physicochemical properties and low levels of contamination. The hydrochemical composition of spring water is primarily controlled by the geological structure of the aquifer, the mineral composition of rocks, climatic conditions, and groundwater residence time. Consequently, the concentrations of dissolved ions may vary considerably among springs located even within the same geographical region.

Natural waters contain numerous dissolved mineral components, among which calcium (Ca^{2+}), magnesium (Mg^{2+}), bicarbonate (HCO_3^-), chloride (Cl^-), sulfate (SO_4^{2-}), iron, and trace elements are of

particular importance. These constituents influence water hardness, mineralization, organoleptic properties, and its suitability for drinking and domestic purposes. Continuous monitoring of these parameters is therefore essential for protecting water resources and ensuring compliance with drinking water quality standards.

Abasha Municipality is situated in the southern part of the Samegrelo–Zemo Svaneti Region in western Georgia. The municipality is characterized by abundant groundwater resources, rivers, wetlands, and favorable hydrogeological conditions that promote the formation of numerous natural springs. Despite the widespread local use of spring water, comprehensive hydrochemical investigations of many springs in the municipality remain limited.

The present study aims to evaluate the hydrochemical characteristics of spring waters in Sujuna Village, Abasha Municipality, by determining the concentrations of major biologically active ions and selected physicochemical indicators. The obtained results provide valuable information on groundwater quality, assess compliance with the Georgian Technical Regulation for Drinking Water, and contribute to the sustainable management and protection of local water resources.

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Pic.1 - Abasha Municipality

Abashi Municipality: The study was conducted in Sujuna Village, located in Abasha Municipality, Samegrelo–Zemo Svaneti Region, western Georgia. Abasha Municipality occupies the southern part of the Samegrelo–Zemo Svaneti Region and borders Martvili Municipality to the north, Khoni and Samtredia Municipalities to the east, Lanchkhuti Municipality to the south, and Senaki Municipality to the west.

The municipality is situated within a lowland area at an elevation of approximately 20–50 m above sea level. The relief is predominantly flat and composed of Quaternary alluvial deposits, including gravel, sand, and clay. The hydrographic network is well developed and includes the Rioni, Abasha, Tskhenistskali, Tekhuri, Noghela, Kovza, and Zana rivers, together with numerous drainage canals and wetlands. These geological and hydrological conditions favor groundwater recharge and the formation of natural springs.

Three representative springs located in Sujuna Village were selected for investigation. Water samples were collected from the Sujuna Spring, the Sabashvilebi Spring, and the Makalatia Spring. These springs are widely used by the local population as sources of drinking water and for domestic purposes. Their hydrochemical characterization is therefore important for assessing water quality, ensuring safe use, and establishing baseline data for future environmental monitoring.

Experimental Part. Methodology for determination of chemical Elements in Water. Water samples were collected from three natural springs located in Sujuna Village, Abasha

Municipality, following standard sampling procedures for hydrochemical investigations. Laboratory analyses were performed at the Iason Mosesvili Hydrochemical Laboratory, Department of Chemistry, Faculty of Exact and Natural Sciences, Akaki Tsereteli State University.

The physicochemical characteristics of the water samples were determined using standard analytical methods widely employed in hydrochemical studies. The pH values were measured potentiometrically. Total hardness, calcium (Ca^{2+}), and magnesium (Mg^{2+}) concentrations were determined by complexometric titration using EDTA. Bicarbonate (HCO_3^-) concentrations were measured by acidimetric titration, while chloride (Cl^-) ions were determined using the mercurimetric method.

Total iron and copper concentrations were analyzed spectrophotometrically using a UN-5100B UV/VIS spectrophotometer following appropriate sample preparation procedures. Sulfate (SO_4^{2-}) concentrations were determined gravimetrically, whereas bromide (Br^-) and total arsenic were analyzed using iodometric methods. Free carbon dioxide (CO_2) was determined by alkalimetric titration, and permanganate oxidizability was evaluated by the permanganatometric method. Dissolved oxygen (DO) and biochemical oxygen demand (BOD_5) were determined according to the Winkler iodometric procedure.

All analytical determinations were performed in accordance with established hydrochemical laboratory protocols, and the obtained results were evaluated with reference to the Georgian Technical Regulation for Drinking Water.

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Results and Discussion. The analytical results obtained for the three investigated springs of Sujuna Village are presented in Table 1. The hydrochemical composition of the spring waters demonstrates only

slight variations among the sampling sites, indicating generally similar hydrogeological conditions within the study area.

Table 1. Hydrochemical Characteristics of Spring Waters in Sujuna Village, Abasha Municipality, Samegrelo–Zemo Svaneti Region, Georgia

N	Local Names of the Spring Waters	pH	mg- eq/L	Mg/L													
			Water Hardness	Mg ²⁺	Ca ²⁺	Total Fe	Cu ²⁺	Cl ⁻	Br ⁻	HCO ₃ ⁻	Free CO ₂	dissolved oxygen	BOD ₅	SO ₄ ²⁻	Permanganate Oxidizability	Total As ლი ქანკვედობს	საერთო დარბზხსი
1	Sujuna Spring	7,3	4,16	21,00	48,80	0,052	0,003	8,38	0,020	4,48	0,38	1,50	24,96	0.0855	0,32	0,011	0,015
2	Sabashvili Spring	7,5	4,24	20,79	51,20	ND	0,001	11,36	0,021	4,92	0,30	1.37	20,42	0.0616	1,14	0,012	0,013
3	Makalatia Spring	7,2	3,96	19,03	48,00	0,066	ND	9,94	0,023	4,72	0,44	1,70	24,13	0.0063	0,24	0,010	

The measured pH values ranged from **7.2 to 7.5**, indicating neutral to slightly alkaline water, which is considered favorable for drinking purposes. Water hardness varied between **3.96 and 4.24 mg-eq/L**, with the highest value recorded in the **Sabashvilebi Spring** and the lowest in the **Makalatia Spring**. These results classify the investigated waters as moderately hard, reflecting the dissolution of calcium- and magnesium-bearing minerals.

Magnesium concentrations ranged from **19.03 to 21.00 mg/L**, while calcium concentrations varied from **48.00 to 51.20 mg/L**. Calcium was the dominant alkaline earth metal in all investigated springs, indicating that groundwater chemistry is primarily controlled by natural interactions between water and carbonate-bearing geological formations.

The concentrations of total iron and copper were very low in all investigated samples. Total iron was below the analytical detection limit in the Sabashvilebi Spring and reached a maximum value of **0.066 mg/L** in the Makalatia Spring. Copper was not

detected in the Makalatia Spring, while only trace concentrations were measured in the remaining springs. These findings indicate the absence of significant contamination from iron- and copper-bearing sources.

Among the major anions, chloride concentrations ranged from **8.38 to 11.36 mg/L**, whereas bicarbonate concentrations varied between **4.48 and 4.92 mg/L**. The relatively stable concentrations of these ions suggest that the investigated groundwater is controlled mainly by natural geochemical processes rather than anthropogenic pollution.

Bromide concentrations exhibited noticeable variation among the investigated springs, with the highest value observed in the Makalatia Spring. Sulfate concentrations remained low in all samples, ranging from **0.0063 to 0.0855 mg/L**, indicating insignificant sulfate enrichment of the groundwater.

The concentration of free carbon dioxide ranged from **0.30 to 0.44 mg/L**, while dissolved oxygen

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varied between **1.37 and 1.70 mg/L**. The highest biochemical oxygen demand (BOD₅) was recorded in the Sujuna Spring (**24.96 mg/L**), whereas the lowest value was measured in the Sabashvilebi Spring (**20.42 mg/L**). The observed differences most likely reflect natural hydrogeochemical conditions rather than anthropogenic impacts.

Permanganate oxidizability values remained low, indicating a limited amount of oxidizable organic matter in the investigated waters. Total arsenic concentrations ranged from **0.010 to 0.012 mg/L**. Although these values are close to the maximum permissible concentration established by the Georgian Technical Regulation for Drinking Water, they indicate that periodic monitoring should be continued to ensure long-term water quality and consumer safety.

Overall, the hydrochemical characteristics demonstrate that the investigated spring waters possess stable physicochemical properties and are generally suitable for drinking and domestic use. The obtained results provide an important scientific basis for future groundwater quality monitoring and environmental management in Abasha Municipality.

Conclusion

This study presents a comprehensive hydrochemical assessment of three natural springs located in Sujuna Village, Abasha Municipality,

Samegrelo–Zemo Svaneti Region, Georgia. The investigated physicochemical parameters exhibited only minor variations among the studied springs, indicating relatively uniform hydrogeological conditions within the study area.

The analyzed concentrations of pH, total hardness, magnesium, calcium, total iron, copper, chloride, bicarbonate, sulfate, dissolved oxygen, biochemical oxygen demand, free carbon dioxide, and permanganate oxidizability generally complied with the requirements of the Georgian Technical Regulation for Drinking Water. The measured concentrations of total arsenic were close to, and in some samples slightly exceeded, the recommended guideline value, indicating the importance of periodic hydrochemical monitoring.

Overall, the investigated spring waters are characterized by satisfactory hydrochemical quality and can be considered suitable for drinking and domestic purposes. The obtained results provide valuable baseline information for groundwater quality assessment in Abasha Municipality and contribute to the sustainable management, rational utilization, and long-term environmental protection of local groundwater resources. Continued monitoring is recommended to identify possible temporal changes in water quality and to ensure the safety of water resources for the local population.

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Contents

		p.
1.	Zhanatauov, S.U. Cognitive model: the Dunning-Kruger effect.	1-14
2.	Otto, O.E., & Gafurova, M. Economic efficiency of CRM systems implementation.	15-20
3.	Gamboa, R.S., Bicalas, M., Abello, A., Gevana, R., & Jagdon, Sh. Understanding students' numeracy competence through the lens of confidence in problem solving and attitude towards mathematics.	21-62
4.	Purtskhvanidze, G., Shubladze, Z., Kurshubadze, T., Bekirishvili, M., & Gvetadze, V. Analysis of the Temperature and Thermal Stress State of Marine Engine Components.	63-68
5.	Chemezov, D., et al. Modeling and analysis of the sheet metal drawing process taking into account normal and shear stresses.	69-72
6.	Chiqovani, M., Makalatia, N., Megrelishvili, N., Endeladze, N., & Ghachava, N. Hydrochemical Investigation of Biologically Active Ions in the Spring Waters of Sujuna Village, Abasha Municipality, Samegrelo–Zemo Svaneti Region, Georgia.	73-78

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